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Socio-Economic and Institutional Factors in Irrigation Return Flow Quality Control
Volume III. Middle Rio Grande Valley Case Study

Colorado State Univ., Fort Collins

Prepared for

Robert S. Kerr Environmental Research Lab., Ada, OK

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Degradation of water quality as a consequence of use in irrigation in the Lower Rio Grande Valley of New Mexico is a largely unavoidable phenomenon. In this region annual allocations of water to irrigated farms, about 2.5 acre-feet per acre, are little more than enough to produce crops. Evaporation and transpiration, occurring because of irrigation, cause concentrations of salts in return flows to be greatly increased, and the addition of these highly saline return flows to a quite limited flow of water in the Rio Grande causes the quality of the river water to be significantly reduced.

It is possible to affect the quantity and quality of return flows by improvement of water transport facilities (canals, laterals and ditches) and by improved management of water on some farms. These two technical improvements can be accomplished by extension of technical assistance through existing federal and state agencies and by cost-sharing programs such as the Agricultural Conservation Program. But it is also possible to achieve improved management of water on farms by facilitating exchanges or sales of allotments among farmers who are members of irrigation districts. Such transfers ordinarily result in improved use of water, i.e., a more conservative use of water and employment of this scarce input in higher-valued uses. The consequence is some reduction in return flows and thus improvement in the quality of water in the Rio Grande River.

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Volume III: Middle Rio Grande Valley Case Study

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FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the Nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: a) investigate the nature, transport, fate, and management of pollutants in groundwater; b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; c) develop and demonstrate pollution control technologies for irrigation return flows; d) develop and demonstrate pollution control technologies for animal production wastes; 3) develop and demonstrate technologies to prevent, control, or abate pollution from the petroleum refining and petrochemical industries; and f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report contributes to the knowledge essential if the EPA is to meet the requirements of environmental laws that it establish and enforce pollution control standards which are reasonable, cost effective and provide adequate protection for the American people.

William C Galegar
William C. Galegar
Director
Robert S. Kerr Environmental
Research Laboratory

PREFACE

This report concentrates on the presentation of a process for implementing technical and institutional solutions to the problem of return flow pollution. This process, under the general title of "Socio-Economic and Institutional Factors in Irrigation Return Flow Quality Control," was centered around a methodological and pragmatic definition of the problem and identification and assessment of a wide range of potential solutions for diverse situations. Four separate but interrelated volumes summarize the study:

Volume I -- Methodology (Main Report)
Volume II -- Yakima Case Study
Volume III -- Middle Rio Grande Case Study
Volume IV -- Grand Valley Case Study.

Volume I (the main report) summarizes the overall research approach of the study; the methodological premises; the nature of the problem; the process for identifying and assessing appropriate solutions; and, some general remarks and conclusions concerning the process of implementation. Volumes II to IV allow for an in-depth presentation of the approach utilized as well as specific findings and recommendations relating to the problems of each case.

The interdisciplinary team has also prepared a separate "executive summary" which is quite a shortened version and with the help of accompanying illustrations attempts to provide in a succinct form the major findings of the study as well as the proposition involved in the identification, assessment and evaluation of potential solutions concerning irrigation return flow.

ABSTRACT

Degradation of water quality, as a consequence of use in irrigation in the Lower Rio Grande of New Mexico, is a largely unavoidable phenomenon. In this region annual allocations of water to irrigated farms, about 2.5 acre-feet per acre, are little more than enough to produce crops of cotton, wheat, barley, sorghum, alfalfa, nuts, and vegetables of several kinds. Evaporation and transpiration, occurring because of irrigation, cause concentrations of salts in return flows to be greatly increased, and the addition of these highly saline return flows to a quite limited flow of water in the Rio Grande causes the quality of the river water to be significantly reduced.

It is possible to affect the quantity and quality of return flows by improvement of water transport facilities (canals, laterals and ditches) and by improved management of water on some farms. These two technical improvements can be accomplished by extension of technical assistance through existing federal and state agencies and by cost-sharing programs such as the Agricultural Conservation Program. But it is also possible to achieve improved management of water on farms by facilitating exchanges or sales of allotments among farmers who are members of irrigation districts. Such transfers ordinarily result in improved use of water, i.e., a more conservative use of water and employment of this scarce input in higher-valued uses. The consequence is some reduction in return flows and thus improvement in the quality of water in the Rio Grande River.

Future efforts to improve the quality of return flows in this region should recognize the inevitable consequence of irrigation, i.e., concentration of salts in reduced volumes of water, and they should include institutional mechanisms, e.g., cost-sharing, water markets, and conservation programs, which are useful to improved allocation and use of water in the region.

This report was submitted in fulfillment of Grant No. R-803572 by Colorado State University under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period between February 14, 1975, to November 14, 1977, and work was completed as of May 4, 1978.

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The authors are deeply indebted to the many farmers, state water resource agency personnel, and many in their capacity as managers and directors of irrigation districts and companies in the various states, who provided invaluable information to the team members during interviews and in supplying reports and data.

SECTION 1

INTRODUCTION

The general goal of this research project has been the development of an effective process for implementing technical and institutional solutions to the problem of irrigation return flow pollution. The present report, based on a case study of the Rio Grande Project in New Mexico/Texas, contains specific findings per the proposed process, namely: a) definition of the problem in its physical, technological, legal, economic, and social parameters; b) identification of potential solutions in relation to key elements of the problem; c) assessment of the potential solutions for significance and acceptability; and d) specification of those solutions which hold greatest promise of efficiency and implementability.

In the main report, the theoretical basis for and the components of an implementation process have been elaborated. In this case study report the experiences of the research team in the practical employment of the process are recounted. Observations, analyses and conclusions are reported and the process is evaluated in terms of its applicability to the study area.

Thus, it should be evident that each case study, although autonomous, should be related to the main report so that specific findings can be interpreted in the context of the more general principles and concepts which are involved in the process of implementation.

DESCRIPTION OF THE AREA

The Rio Grande rises at an elevation of over 14,000 feet (4,267.2 m) on the eastern slope of the San Juan Mountains in southern Colorado. After flowing briefly eastwards in Colorado, the River turns southwards and flows 400 miles (644 km) through New Mexico. In lower New Mexico, the River turns to the southeast and forms the boundary between Texas and the Republic of Mexico to the point of discharge into the Gulf of Mexico. The total length of the River is about 1,900 miles (3,057 km.) and the outer rim of the basin embraces a total area of 335,500 square miles (868,945 km^2).

The River is generally considered to have two regimes, being divided into an upper and lower basin at Fort Quitman, 80 miles (129 km) downriver from El Paso, Texas. Above Fort Quitman, nearly all of the River's waters are consumed by irrigation in Colorado, New Mexico, Texas, and Mexico. In the lower basin, the River develops its flow mainly from tributaries in Mexico and is virtually restarted by inflow from the Rio Conchos above Presidio.

Approximately 99 percent of the water supply of the Upper Rio Grande Basin comes in equal amounts from Colorado and New Mexico. The Upper Basin is divided naturally into three divisions: The San Luis section in Colorado, the Middle section in New Mexico, and the Elephant Butte-Fort Quitman section in New Mexico, Texas and Mexico. This section is the subject area of this report.

The two million acre-feet Elephant Butte Reservoir of the U.S. Bureau of Reclamation's Rio Grande Project is located at the head of the study area and regulates river inflow for use as far as Fort Quitman. The Rio Grande drainage basin above Elephant Butte Dam contains 25,923 square miles (67,141 km^2) and has an average annual runoff of about 899,000 acre-feet (110,847 ha.-m) (1894-1972) at San Marcial, immediately above Elephant Butte Reservoir.

Immediately below Elephant Butte, Caballo Reservoir regulates discharges released for power production at Elephant Butte Dam. It is used additionally for storing intervening tributary inflows. Below Caballo, the section is a succession of valleys separated by canyons and narrows. The river bottom lands of the valleys are extensively irrigated, with this ribbon of agricultural development having a maximum width of only 5 miles (8.05 km). The Rincon and Mesilla Valley and the northern half of El Paso Valley, on the Texas side of the River, comprise the 178,196 acre (72,169 ha) area of the Rio Grande Project. In the southern half of the El Paso Valley on the Texas side is the Hudspeth County Conservation and Reclamation District, comprised of 18,342 (7,429 ha) irrigable acres. An area of several thousand hectares is irrigated on the Mexican side of the River immediately below Juarez.

DEVELOPMENT OF IRRIGATION

Recorded history of the Rio Grande Valley begins with its discovery by the Spanish explorers under Coronado in 1540. At this time, Indians in the Middle Valley were cultivating land and bringing water to it by irrigation ditches as their ancestors had long done. The area of irrigated land probably exceeded 30,000 acres (12,150 ha). Below the Middle Valley, the original Indian inhabitants were not agricultural people and did not cultivate their lands.

The first white settlement in the study area was founded in 1659 on the southern side of the River where the Mexican city of Juarez now stands. The Spanish colonists practiced irrigation from the time of their first occupation of the country. A large increase in the irrigated area took place following 1680 when refugees from the Indian rebellion in New Mexico arrived. In 1851, American reconnaissance forces found an area of about 32,000 acres (12,960 ha) being irrigated. Although early Spanish settlements were confined to the immediate vicinity of El Paso because of hostile Indians, large areas of land were under cultivation in the Mesilla Valley by the 1860's.

Following the water shortages of the 1890's and the subsequent complaints by Mexico, construction of Elephant Butte Dam was authorized by Congress in 1905. The dam, diversion dams and canal systems of the Rio Grande Project were completed in 1916. By 1925, a complete system of open drains was constructed. Land owners on the Rio Grande Project were represented by the Elephant Butte Irrigation District in New Mexico and the El Paso County Water Improvement District No. 1 in Texas. In 1925, the Hudspeth County Conservation and Reclamation District No. 1 was organized. Under a Warren Act Contract with the United States, the district makes direct diversion of drainage and waste waters of the Rio Grande Project.

Nearly all of the irrigation in the Elephant Butte-Fort Quitman section is by surface methods. The lands are flat and easily served by gravity diversions. A wide range of crops are grown, with the principal crops being cotton, alfalfa, hay, peppers, pecans, onions, and lettuce.

THE WATER QUALITY PROBLEM

A concern for the quality of the irrigation water has been apparent since the early days of the Rio Grande Project. As early as 1918, the U.S. Bureau of Reclamation (USBR) began collecting water samples from some of the drains in the project area to determine the total dissolved solids (TDS). This program of sampling was continued through 1936. To supplement the inquiry of the National Resources Committee, additional samples were taken in 1929-30, 1933-34, and 1936. For each year, from 1934 to 1963, salt loads were computed for each section of the Rio Grande Project by the U.S. Salinity Laboratory. These programs were in addition to the monitoring of the USBR and the U.S. Geological Survey (USGS).

Salt concentrations at a given point in the Rio Grande have remained relatively constant during the period for which records are available. However, as flow rates decline with distance from Elephant Butte, the concentration of salts in the river increases. This is due in part to the salt concentrating effects of irrigation. The result is that irrigators in the lower valley are receiving poorer quality water as a result of irrigation above them. In addition, when less than usual amounts of irrigation water are available, there is no leaching of salts from the soil profile. So, it becomes difficult to maintain a favorable salt balance in the crop root zone. The consequence is a salt buildup in the land.

OBJECTIVE OF THIS REPORT

The purpose of this report is to identify the specific causes of the water quality problems in the study area, to identify alternative solutions to those problems, to analyze these alternatives, and finally, to evaluate the alternatives in terms of implementability.

SECTION 2

CONCLUSIONS

Irrigation return flow is generally considered to be a non-point source of pollution. Control has not been accomplished because an inappropriate control mechanism has been applied. In this case study, the parameters of the return flow problem have been carefully explicated and appropriate solutions have been identified by evaluation of several potential or alternative solutions.

This case study has been found to be somewhat unique in comparison to others studied and possibly in comparison to many other irrigated areas. In this portion of the Rio Grande Valley, from Elephant Butte Reservoir to Fort Quitman, Texas, water use in agriculture is relatively efficient. The annual allocation to irrigators is 2.5 to 3.0 acre-feet per acre (.76 to .91 ha-m/ha), smaller than that of most irrigated areas, and water is conservatively used. Though improvements are possible, transport and distribution facilities function reasonably well, irrigation methods are generally appropriate to circumstances, and water is logically allocated to higher value crops. There is a problem of quality of water in the river, and it is largely attributable to return flows from irrigation. But increasing concentrations of salt in return flows and in the river are a largely unavoidable consequence of irrigation. Opportunities to affect quality of return flows are limited, and the possibility of significantly affecting quality of water in the river is small.

SPECIFIC FINDINGS

1. This project area encompasses two states (New Mexico and Texas) and an interstate/international river regulated by compact among three states and a treaty between two nations.

2. New Mexico applies the appropriation doctrine to surface and ground waters. Texas applies both riparian and prior appropriation doctrines for surface waters, except that since the 1967 Water Rights Adjudication Act, riparian right claimants are required to file their claim with the Texas . Water Rights Commission. Ground water is withdrawn according to the absolute ownership doctrine.

3. Both New Mexico and Texas have separate agencies for water quantity and quality control with the top water quantity administration a member of the pollution control commission (New Mexico) or Board (Texas).

4. In neither state do the state water personnel perceive the Rio Grande project area as a significant water quality problem from irrigation return flows to surface waters. Ground water contamination may be more significant. Consequently, neither state has adopted the National Pollutant Discharge Elimination System (NPDES) program, nor regulations governing irrigation return flow quality control. New Mexico, in fact, statutorially recognizes reasonable degradation for agricultural water use.

5. Water is distributed to irrigators by public irrigation districts in each state under water rights held either by the districts or by the Bureau of Reclamation.

6. Water transfers, i.e., selling of annual allotments, are common in the Elephant Butte Irrigation District, but not widely practiced in the El Paso District.

7. The irrigation return flow quality aspects of the river are not perceived by state officials as significant to the international nature of the river in the project area.

8. The deterioration in water quality of the Rio Grande in passing through the Elephant Butte Project is due principally to the concentrating effect of irrigation. The overall salt balance of the project is unfavorable, resulting in the quality of the water leaving the project being better than that which would result from a project having a favorable salt balance. This does not mean, however, that the only method of improving existing water quality would be to retire land from irrigated agriculture (although this would be one way of improving quality).

9. Some areas within the upper portion of the project area maintain a favorable salt balance, which is to their own benefit but to the detriment of the downstream waters. (However, more recent data is needed to evaluate this trend.) Water quality in the El Paso Valley would improve if the consumptive use of the upper valleys was decreased.

10. Some local practices exacerbate the water quality problem. The abundance of deep percolation is evidenced by the high volume of drain flows. Further research, such as that currently being carried out by New Mexico State University, is necessary to determine reasonable leaching fractions and the most suitable timing of leaching applications. If leaching fractions could be reduced, the downstream areas could be provided with higher quality water released from Caballo Reservoir, rather than relying on low quality return flows.

11. There is a perception by many farmers that those who continue to survive are those who utilize their water as efficiently as can be expected given the existing circumstances.

12. There is evidence that farmers fail to understand their common problems, and so they are slow to act together on issues like rehabilitation of water distribution facilities.

13. There is a sensitivity to regional problems and interests which is manifested in the Rio Grande Environmental Project organization and in cooperative efforts of irrigation districts.

14. There is resistance at state and local levels to programs of water quality control which are imposed on water users without consultation or explanation.

15. There is no internalization of pollution costs by farmers using water in irrigation so there is little incentive to reduce return flows.

16. There is resistance to policies and programs designed to improve water quality which will raise the price of water to users. Water is one input over which farmers have some control. In their districts, they control delivery costs.

OVERALL FINDINGS

Looking for more general findings, the following brief remarks summarize the overall conclusions of the study:

1. Mesilla Valley is characterized predominantly by salt concentration rather than salt pickup effects due mainly to the use of water. This water use contributes to salinity levels greater than acceptable in drinking standards for both cities of El Paso and Juarez.

2. The study area is characterized by increasing competing and conflicting water demands, which result from an expanding urban demand in El Paso and Juarez, as well as from potential further agriculture.

3. The State of New Mexico has taken the stand that irrigation return flow quality is not sufficiently significant to require the employment of the NPDES permit system.

4. There does exist in the area a market system for use of water which does result in water use for higher-valued crops.

5. In the general study area, most farmers perceive that they are doing the best they can and, thus, there are no particular new incentives for further improvements. There are "others" who are blamed for specific instances of water quality degradation, but corrective actions are not feasible.

6. Given the two states involved, questions of return flow are "localized" in the sense that problems are seen as part of Texas and not of New Mexico.

7. There is free-floating anxiety that the State Department will give ground water to Mexico. In such a case, water shortages would increase and, thus, contribute to further pollution. While presently El Paso takes little water from the river, given the overall limited water supply and present or future significant water withdrawal creates problems.

8. The people in El Paso and further downstream question the nature or significance of irrigation return flow since virtually no water is left in the river.

9. Finally, while localization of problems perception may be true, it is also equally true that strong regional orientation is evidenced by the viability of REGREP.

SECTION 3

RECOMMENDATIONS

The following recommendations derive from the investigation of the study area and are herein suggested to EPA, the state water agencies, the irrigation district managers, and water users:

1. Because of the interstate nature of the river, uniformity between state laws for ground water and beneficial use should be sought.

2. The water trading practice of the Elephant Butte Irrigation District should be promoted in other districts as an incentive for more efficient water use through the market mechanism.

3. Sprinkler and trickle irrigation should be developed in appropriate circumstances as a means for reducing a consumptive use of water, thereby leaving more water in the river for dilution.

4. Studies by New Mexico State University and by USGS regarding ground water should be continued in order to provide more meaningful answers and insights into appropriate technologies for alleviating the salt load in the Rio Grande.

5. A water management improvement program should be implemented to include the following components:

   a. system rehabilitation to allow timely and accurate delivery of water so that existing constraints to better on-farm water management may be removed;

   b. an irrigation scheduling service to farmers to allow optimal quantities of water for crop production to be applied with a minimum of waste;

   c. measurement of irrigation water to the farm to allow the application of the desired quantity of irrigation water;

   d. a change in irrigation methods in some cases (e.g., trickle irrigation for pecans, sprinkler irrigation for field crops) to reduce consumptive use and waste due to nonuniformity of water application.

6. A detailed study should be made of the feasibility of building an aquaduct from Caballo Dam to El Paso or beyond, in conjunction with the irrigation system rehabilitation in the Elephant Butte Irrigation District. This would allow water of equal, high quality to be delivered to all parts of the Elephant Butte Project, to the city of El Paso, and to Mexico.

SECTION 4

CHARACTERISTICS OF THE STUDY AREA

PHYSICAL CHARACTERISTICS

Hydrologic Basin

The Rio Grande Basin from Elephant Butte to Fort Quitman contains an area of about 8,000 square miles (20,720 km^2) stretching over a distance of 210 miles (338 km) (Figure 1). Inflow to this section of the Valley is measured at San Marcial at the head of Elephant Butte Reservoir. From Elephant Butte Dam the river flows into Caballo Reservoir, which is immediately below the town of Truth or Consequences. Caballo Dam, 22 miles (35 km) below Elephant Butte, was completed in 1938 and is used to store water for winter generation of electricity at Elephant Butte, and for irrigation during the summer. Elephant Butte Reservoir has a capacity of 2,194,000 acre-feet (270,520 ha-m) (based upon 1957 Silt Survey corrections, while original capacity was 2,638,000 acre-feet (325,265 ha-m)), and Caballo Reservoir has a capacity of 343,990 acre-feet (42,414 ha-m) (based upon 1958 Silt Survey corrections, while original capacity was 345,870 acre-feet (42,646 ha-m)).

From San Marcial to Caballo Dam, the flanking hills are close to the river and there is little flood plain. Below Caballo Dam, the Basin is a narrow strip of green along the flood plain with arid and semi-arid mountainous regions on both sides. The Basin is broken by natural barriers into three distinct valleys. These are, respectively, the Rincon, Mesilla and El Paso Valleys. The Rio Grande is confined between levees as it passes through each of the valleys.

The Rincon Valley is about 30 miles (48 km) long and the flood plain has a maximum width of about two miles. Water for the 16,340 irrigated acres (6,618 ha) is diverted from the Rio Grande at Percha Diversion Dam approximately 2 miles downstream from Caballo Dam. The Valley terminates at Selden Canyon, a narrow defile about 7 miles (11 km) long, from which the River emerges into the Mesilla Valley. The Mesilla Valley is about 55 miles (89 km) long, with a maximum flood plain width of about 5 miles (8 km) opposite Las Cruces. Irrigation water is diverted at Leasburg Dam at the upper end of the Valley and at Mesilla Diversion Dam near Mesilla. The total irrigated area is 85,490 acres (34,634 ha). The Valley ends at "The Pass," four miles above El Paso.

Below El Paso, the River is the boundary between Texas and Mexico. The El Paso Valley extends about 90 miles (145 km) from "The Pass" to the gorge

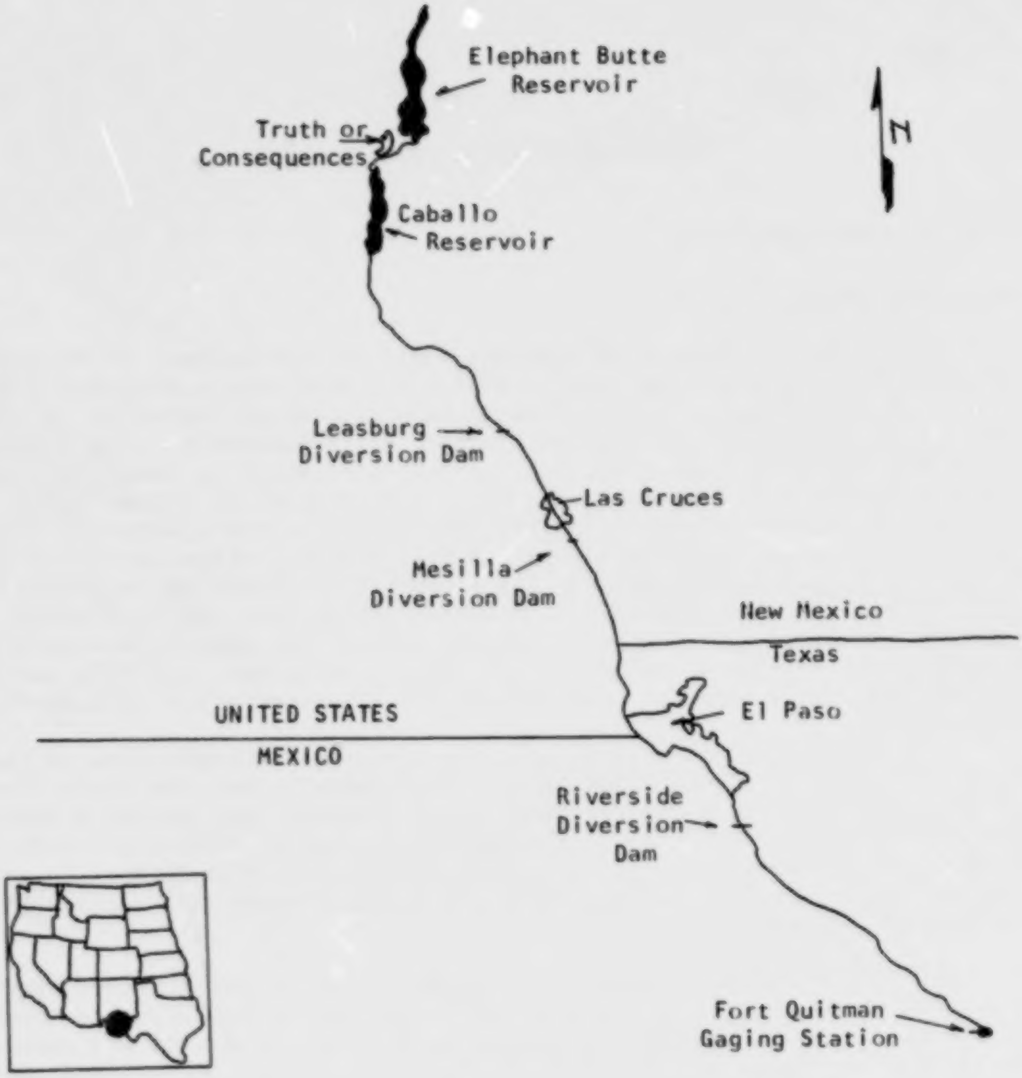

Elephant Butte Reservoir
Truth or Consequences
Caballo Reservoir
N
Leasburg Diversion Dam
Las Cruces
Mesilla Diversion Dam
New Mexico
Texas
UNITED STATES
MEXICO
El Paso
Riverside Diversion Dam
Fort Quitman Gaging Station

Figure 1. The Middle Rio Grande Valley.

about 10 miles (16 km) below Fort Quitman. The flood plain is generally 4 to 6 miles wide (6-10 km). The area on the Mexican side is commonly referred to as Juarez Valley. Two diversions supply irrigation water to the El Paso Valley. The American Dam diverts water into Franklin Canal on the northern side of El Paso. Riverside Heading is located approximately 20 miles (32 km) below American Dam and diverts water into the Riverside Canal. The total irrigated area is 57,820 acres (23,417 ha). Two miles below American Dam the International Dam diverts water into the Acequia Madre for use on the Mexican side of the River.

The Hudspeth County Conservation and Reclamation District No. 1 receives operating and drainage return flow water reaching the lower end of the Rio Grande Project and has an area of about 18,000 acres (7,290 ha), capable of being irrigated through a series of small reservoirs and canals extending along the Rio Grande Valley for a distance of 40 miles (64 km) below the project.

In the northern part of the study area, the western boundary is formed by the Mimbres Mountains, about 25 miles (40 km) from the River. The boundary cuts eastward to the Sierra de Las Uvas where the Mimbres Range ends, and then southwards to the Mexican border. The eastern boundary of the Basin runs roughly parallel to the Rio Grande, about 5 to 10 miles (8-16 km) away, running southwards to join the Franklin Mountains which terminate the Mesilla Valley above El Paso. Below El Paso, the boundary turns southeastwards and parallels the River at a distance of about 20 miles (32 km).

Elevations along the River range from 4,450 feet (1,348 m) at the point of inflow at San Marcial to 3,450 feet (1,052 m) at the point of outflow at Fort Quitman. The highest elevations in the Basin are along the Continental Divide and the San Mateo Mountains to the west of Elephant Butte Reservoir, being generally over 8,000 feet (2,438 m), with Blue Mountain having an elevation of 10,336 feet (3,150 m). Below El Paso, the Basin boundary has an elevation of about 5,000 feet (1,524 m).

Tributaries to the Elephant Butte-Fort Quitman section of the River consist only of arroyos which are dry most of the time but subject to flash floods resulting from thunderstorms. The principal arroyos enter from the west between San Marcial and Rincon Valley and are, in downstream order, Milligan Gulch, San Juan Creek, Nogal Canyon, San Jose Arroyo and Alamosa, Chuchillo Negro, Palomas, Seco, Las Animas, Percha, Tierra Blanca, and Berrenda Creeks. The first five are tributaries to Elephant Butte Reservoir and the next four are tributaries above Caballo Dam. Percha Creek has also been diverted to Caballo Reservoir. Many of the smaller ephemeral arroyos have been dammed for flood control.

Topography and Soils

The irrigated soils of the study area are contained in the alluvial flood plain of the Rio Grande. In New Mexico, these soils have been classified by the New Mexico State University Agricultural Experiment Station as belonging to the Gila-Glendale-Vinton association. These soils, which are dominantly deep and highly stratified, are formed in alluvium of mixed origin. The textures of the surface layers cover the gamut from sand to clay; but medium, moderately fine and fine are the more common textures.

Gila soils, the most extensive in this association, usually have a surface layer of calcarous light brownish-gray or pale brown loam. This is underlain to a depth of five feet or more by stratified loams and sandy loams, Also, in close association with the Gila soils, and commonly included in the same mapping unit, are soils with medium-textured subsoils. These soils differ from the Gila soils in that they contain more strata of heavy loam, sandy clay loam, light clay loam, and very fine sandy loam.

Glendale soils have a surface layer of calcareous light brownish-gray to pale brown loam or clay loam over a stratified subsoil of silt loam, silty clay loam and clay loam. Thin strata of silt and clay that are very slowly permeable commonly occur in the subsoil. The substratum is typically stratified and moderately course-textured to moderately fine-textured.

Vinton soils usually have a pale brown, fine sandy loam or loamy fine sand surface layer. The subsoil consists of stratified loamy sand, loamy fine sand, and sandy loam with occasional thin strata of loam, silt loam, or very fine sandy loam. The substratum is similar except that it is slightly coarser-textured, with loamy fine sands and sands being dominant.

Armijo, Brazito, Belen, Agua, and Anapra soils are also common in this association. The Armijo soils are deep, fine-textured and slowly permeable. The Anapra soils consist of light-colored, calcareous, medium-textured and moderately fine-textured soils underlain by clean sand at depths of 18 to 36 inches (46-91 cm). The Brazito soils are underlain by clean sand at depths of 6 to 18 inches (15-46 cm). Aqua soils are similar to those of the Gila series but differ in that they are underlain by clean sand at depths of 20 to 36 inches (51-91 cm). The Belen soils (like those of the Armijo series) are clayey, but differ in that they are underlain at depths of 20 to 30 inches (51-76 cm) by permeable sandy loams and loams. Miscellaneous land types, including riverwash, arroyo bottoms and the Rio Grande, comprise about five percent of this association.

In Texas, the Rio Grande flood plain has deep nearly level soils that have loamy very fine sand to silty clay loam underlying material. These soils have been classified by the Soil Conservation Service of the U.S. Department of Agriculture (USDA) as belonging to the Harkey-Glendale association.

The Glendale soils, which have been described above, account for probably less than 20 percent of the area. The Harkey soils account for nearly 40 percent, with minor soils accounting for the remainder. Harkey soils typically have a surface layer of pink, calcereous silty clay loam about 12 inches (30 cm) thick. The surface layer is underlain by stratified layers of silt loam, loamy very fine sand, very fine sandy loam and silty clay loam. The underlying material has an average texture of loam. Also in this association are small areas of Saneli, Tigua, Gila, Anapra, Vinton and Brazito soils.

Climate

The climate of the study area is characterized by an abundance of sunshine throughout the year, by high but not extremely high daytime temperatures in summer and by low humidity, scanty rainfall and relatively cool winters typical of arid areas. Temperature and precipitation data for Caballo Dam *and El Paso are shown in Table 1. Extensive data for the lower end of the* study area are not available, but available data from Fabens indicates that it does not differ markedly from El Paso.

Rainfall in the area is too light for the growth of any vegetation except desert plants. Dry periods that last for several months without appreciable rainfall are not unusual. More than half the yearly precipitation occurs in summer during brief, but at times heavy, thunderstorms. Small amounts of snow fall nearly every winter, though snow cover rarely amounts to more than an inch and seldom remains for more than a few hours.

During summer, the daytime temperature frequently rises above 90 F (32°c) and occasionally above 100°F (37.8°c), then usually falls to the 60's (16-21°c) at night. The highest recorded temperature at both Caballo Dam and El Paso is 109°F (43°c).

TABLE 1. AVERAGE TEMPERATURE AND PRECIPITATION AT
CABALLO DAM AND EL PASO, 1941-1970

Month	Caballo Dam		El Paso	
	Temperature (°c)	Precipitation (mm)	Temperature (°c)	Precipitation (mm)
January	5.1	9	6.4	10
February	7.7	8	9.1	11
March	10.7	6	12.6	10
April	15.7	6	17.7	6
May	20.1	5	22.3	8
June	25.2	14	26.8	15
July	27.2	40	27.9	39
August	26.1	47	26.9	28
September	22.6	37	23.4	29
October	16.6	18	17.8	20
November	9.8	6	10.7	8
Decmeber	5.5	12	6.9	13
ANNUAL	16.0	109	17.4	197

Temperatures on the average winter day rise to 55 to 60°F (13°-16°c) and drop below freezing on about half the nights in December and January. Temperatures below 10°F (-12°c) are rare, having occurred at El Paso on only 28 days in more than 80 years of record, although an extreme of -8°F (-22°c) has been recorded.

At El Paso, the relative humidity averages about 51 percent at 6 am, 35 percent at noon, 26 percent at 6 pm, and 40 percent at midnight. If the temperature is high, the relative humidity is generally quite low. If the temperature is above 90° F (32°c) in April, May or June, the average humidity is between 10 and 14 percent. When the temperature is above 90°F (32°c) in July, August and September, the average humidity is between 22 and 24 percent.

The average length of the frost-free season is 220 days at Elephant Butte Dam and 248 days at El Paso. Sunshine is abundant year round, although slightly lower in the winter months, and occurs an average of nearly 80 percent of the possible hours at Elephant Butte and 82 percent at El Paso. Evaporation from a Class A pan at Elephant Butte Dam averages 118 inches (2,997 ml) annually, or 92 inches (2,336 ml) during the frost-free period. Average annual Class A pan evaporation at El Paso is 105 inches (2,667 ml).

ECONOMIC CHARACTERISTICS

General Composition

While nonagricultural industries are increasingly important to the economy of the study area, agriculture remains a fundamental element. The 150,000 acres (60,750 ha) of irrigated land produce a large variety of high-value crops. Cotton and pecans are crops of national significance. In the Rincon and Mesilla Valleys, there is produced 25-30 percent of all cultivated crops in New Mexico. If production from the El Paso Valley is added, the total is about 35 percent of all crops in that state.

Irrigated agriculture is also the basis for important agri-businesses. These include the firms who supply the seeds, fertilizers and equipment as well as the processors and shippers of produce. Most of these are located in Las Cruces and El Paso. Their business activities are significant to the regional economy.

The largest employers of persons in the project area are the variety of governmental agencies. The White Sands Apollo testing facility employes some 12,000 people, and an even larger number are employed at the missile range. Numerous Federal agencies engaged in resource management, defense and public services employ several hundred people, and New Mexico State University at Las Cruces has a large payroll.

The development of the space industry in the area prompted the growth of several manufacturing and tool-making firms. They supply many of the needs of the firms and government agencies engaged in space research.

Relatively cheap labor has caused other industrial growth in El Paso. This city is now a center for the manufacture of clothing. Also located there is a steel mill and some other "heavy" industries.

With industrial development there have been also expansions in trade and services, the real estate, finance and insurance sectors, and the wholesale and retail sectors. Similarly, the public utilities and transportation sectors have grown. Employment has increased significantly in these allied or supportive industries, though the unemployment rate has changed but little.

Recently, efforts have been made to develop the recreational potential of Elephant Butte and Caballo Reservoirs. With the assistance of realtors and developers from the Albuquerque area, significant growth has been realized.

Hudspeth County in Texas is a relatively depressed area. A few small towns continue to exist within the irrigated area along the river, but the economic activity of El Paso does not spill over significantly into the countryside.

Agricultural Production

There are more than 3 million acres (1,215,000 ha) of land within the study area (the Lower Rio Grande region of New Mexico plus that portion of the Basin from the Texas line to Fort Quitman). But most of this land is semi-arid to arid range land. Only 5 percent is irrigated; about 6.5 percent is irrigable and suited for crop production. This land is in the river bottom and is included within the boundaries of irrigation districts.

High value crops occupy most of the irrigated land. The more important ones are included in the list below:

Barley
Sorghums
Wheat
Alfalfa
Improved pasture
Peppers
Tomatoes
Corn silage
Cotton
Cabbage
Lettuce
Onions
Pecans

All these crops are produced in the Rincon and Mesilla Valleys, where there are both good water and suitable soils. But a smaller number are produced in the El Paso Valley, because of the lower quality of water available there. And, in the Hudspeth Irrigation District, only hay and a few other crops of relatively low value are produced. The irrigation water available there is return flows from districts above and "wild water," or runoff from rainstorms.

Crops, crop yields and crop values for the irrigated lands of the Rio Grande Project, New Mexico-Texas and Hudspeth County Conservation and Reclamation District No. 1 are shown in Table 2. The large number and variety of crops are evident in this table, and the significant values of the crops are well established.

Role of Irrigation

The waters of the Rio Grande are used principally for the irrigation of agricultural crops. There is some use of river water by the city of El Paso, and recent studies suggest increased demands for river water for

TABLE 2. CROP PRODUCTION, YIELDS AND VALUES, MIDDLE RIO GRANDE PROJECT AND HUDSPETH IRRIGATION DISTRICT, 1972*

Crops Harvested in Irrigation Rotation	Acres	Unit	Yield		Value of Crops		
			Per Acre	Total	Per Unit	Per Acre	Total
CEREALS							
Barley, 48#	7,771	Bu.	81.0	628,481	$ 1.36	$ 109.73	$ 852,719
Corn, 56#	2	Bu.	15.0	30	1.60	24.00	48
Oats, 32#	529	Bu.	66.0	34,650	1.33	86.97	46,008
Rice		Cwt.					
Rye		Bu.					
Sorghums (sorgo,kaffir,etc.), 50#	3,168	Bu.	57.0	180,340	1.35	76.66	242,856
Wheat, 60#	114	Bu.	97.0	11,063	1.67	162.18	18,489
Other Cereals		Cwt.					
Total Cereals	11,584					100.15	1,160,120
FORAGE							
Alfalfa hay	26,094	Ton	5.3	138,597	32.65	173,41	4,525,025
Other hay	469	Ton	4.1	1,946	26.56	110.20	51,684
Irrigated pasture, 0.4 ton	3,399	AUM	13.5	45,852	8.74	117,84	400,547
Corn fodder	147	Ton	12.6	1,859	4.90	61.97	9,110
Silage or Ensilage	2,243	Ton	14.9	33,433	6.71	100.03	224,370
Crop residue: Beet tops		Ton					
Stubble, stalks, etc.		AUM					
Straw (all kinds)		Ton					
Root crops (carrots, etc.)		Ton					
Other forage		Ton					
Total Forage	32,352					161.06	5,210,736
MISC. FIELD CROPS							
Beans, castor		Cwt.					
Beans, dry and edible		Cwt.					
Broomcorn		Ton					
Cotton, lint (Upland)500# gross	37,867	Bale	1.5	56,928	104.00	156.35	5,920,512
Cotton, seed (Upland)		Ton	0.6	23,019	53,00	32.22	1,220,007
Cotton, lint (Am.-Pima) 500# gross	37,708	Bale	0.88	33,210	182.00	160.29	6,044,220
Cotton, seed (Am.-Pima)	Ton	Ton	0.3	13,000	53.00	18.27	689,000
Hops		Ton					
Peppermint		Lb.					
Spearmint		Lb.					
Sugar Beets		Ton					
Soybeans		Bu.					
Other Miscellaneous field crops		Ton					
Total Miscellaneous Field Crops	75,575					183.58	13,873,739
VEGETABLES							
Asparagus		Cwt.					
Beans (processing)		Ton					
Beans (fresh market)		Cwt.					
Broccoli	187	Cwt.	296.8	55,505	2.39	708.40	132,470
Cabbage		Cwt.					
Cauliflower		Cwt.					
Celery		Cwt.					
Corn, sweet (processing)		Cwt.					
Corn, sweet (fresh market)	22	Cwt.	20.0	440	5.45	109.00	2,398
Cucumbers	163	Cwt.	106.6	17,372	3.19	339.98	55,417
Greens (kale, etc.)		Cwt.					
Lettuce	3,403	Cwt.	193.1	657,126	4.94	953.19	3,243,699
Melons: Cantaloupes, etc.	83	Cwt.	100.7	8,355	5.65	568.47	47,183
Honey Ball, honeydew, etc.	1	Cwt.	269.0	538	6.00	1,614.00	3,228
Watermelons	10	Cwt.	110.2	2,202	3.17	697.00	6,970
Onions, dry	2,900	Cwt.	370.2	1,073,622	5.64	2,086.87	6,051,925
Onions, green		Cwt.					
Peas, green (processing)		Ton					
Peas, green (fresh market)	2	Cwt.	9.0	18	3.00	27.00	54
Peppers (all kinds)	4,230	Cwt.	80.6	341,111	6.50	523.78	2,215,591
Potatoes, early	7	Cwt.	150.0	1,050	6.00	900.00	6,300
Potatoes, late		Cwt.					
Squash	4	Cwt.	166.0	664	8.00	1,328.00	5,312
Sweet Potatoes	1	Cwt.	50.0	50	8.00	400.00	400
Tomatoes (canning)	628	Ton	9.6	6,044	38.21	367.74	230,941
Tomatoes (fresh market)	6	Cwt.	32.3	194	9.01	291.33	1,748
Other vegetables	11	Cwt.	6.0	66	136.36	818.18	9,000
Total Vegetables	11,659					1,030.33	12,012,636
TOTAL NURSERY	126					4,525.79	570,250

(continued)

TABLE 2 (continued)

Crops Harvested in Irrigation Rotation	Acres	Unit	Yield		Value of Crops		
			Per Acre	Total	Per Unit	Per Acre	Total
SEEDS							
Alfalfa	7	Cwt.	1.0	7	$ 50.00	$ 50.00	$ 350
Clover (all kinds)		Cwt.					
Corn		Cwt.					
Flaxseed		Cwt.					
Grass (all kinds)		Cwt.					
Lettuce		Cwt.					
Onion	100	Cwt.	12.7	1,267	140.00	1,773.80	177,380
Pea		Cwt.					
Potato (all kinds)		Cwt.					
Sugar beet		Cwt.					
Other seed		Cwt.					
Total Seeds	107					1,661,03	177,730
FRUITS							
Apples		Ton					
Apricots		Ton					
Berries (all kinds)		Cwt.					
Cherries		Ton					
Citrus: Grapefruit		Cwt.					
Lemons and limes		Cwt.					
Oranges and tangerines		Cwt.					
Dates		Ton					
Grapes, table	2	Ton	1.5	3	300.00	450.00	900
Grapes, other		Ton					
Olives		Ton					
Peaches		Ton					
Pears		Ton					
Prunes and plums		Ton					
Other fruits		Ton					
Total Fruits	2					450.00	900
NUTS							
Almonds		Ton					
Pecans	6,617	Cwt.	12.1	80,100	55.00	665.79	4,405,500
Walnuts		Ton					
Other nuts		Ton					
Total Nuts	6,617					665.79	4,405,500
FAMILY GARDENS AND ORCHARDS	676	Value				62.77	42,435
TOTAL ALL CROPS	138,698	Ton					$37,454,046
Less Multiple Cropped	3,664						
TOTAL HARVESTED CROPLAND & PASTURE	135,034					$277.37	$37,454,046

* Production data for 1972 used for illustrative purposes because of significant increase in prices of some crops in 1973-74.

nonagricultural uses. But in the near future allocation will closely approximate that of the past. Irrigation will claim most of the water of the Rio Grande.

Table 3 shows the acreages of irrigable and irrigated land in the study area. When the 12,000 acres (4,860 ha) of the Hudspeth County district are counted, the total area irrigated is 150,000 acres (60,750 ha). The Elephant Butte District is much the largest in the project area. Hudspeth District is small, with only 12,000 (4,860 ha) irrigated acres and there is some question that this is a firm figure. There may be fewer acres irrigated. The boundaries of the El Paso District Change a bit as new lands are added to compensate for encroachment of the urban area. But the acreage irrigated in the district is fairly constant.

Table 4 shows the number of full- and part-time farms which are served by irrigation districts in the study area and the suburban area that is irrigated. The data reflect the urban encroachment and suggest the diversion of water from traditional agricultural uses to gardens and horticultural projects.

SOCIAL CHARACTERISTICS

Human Ecology

The Rio Grande Valley incorporates part of Sierra and Dona Ana Counties in New Mexico, and El Paso and Hudspeth in Texas. The general population characteristics show that the median year of education is approximately 11.0 years; the unemployment rate is approximately 3.8 percent for men and 6.5 percent for women; the percentage of farmers or farm managers in the Valley runs from 0.3 percent in El Paso to 14.9 percent in Hudspeth, with Sierra and Dona Ana averaging 3.6 percent and 2.2 percent, respectively. The median income runs from $4,833 in Sierra to $7,792 in El Paso, and the per capita income generally falls in the range of $1,652 in Hudspeth to $2,359 in El Paso (for the series of background tables, see Appendix A). There is a rapid rate of urban growth in the El Paso area; there is a large rural nonfarm population in the Valley; and the majority of the land is owned by independent farmers.

These are some of the critical parameters that must be considered when one is attempting to introduce change into a social system. They affect the way people think and act relative to alternative ways of doing things. Introduction of measures to affect water quality will involve significant changes in economic activities. Response of affected persons will depend on socioeconomic circumstances.

A significant phenomenon in the Las Cruces and El Paso areas (Appendix A) is urbanization. An urban area is described as an area having a population of 2,500 or more. The Bureau of the Census depicts an urbanized area as a centralized city of 50,000 population surrounded by an urban territory. The urban area of El Paso in 1970 contained 337,471 people, while that of Las Cruces was 43,735. The change in population from 1960 was +28.9 percent in Las Cruces and +16.5 percent in El Paso. Projections for the 1970 to

TABLE 3. IRRIGABLE AND IRRIGATED AREAS, RIO GRANDE PROJECT AND HUDSPETH DISTRICT, 1974.*

Type of Irrigation Service and Division, District, Unit, Etc.	IRRIGABLE AREA FOR SERVICE			Total Irrigable Area acres (ha)	Total Area Irrigated acres (ha)	GROSS CROP VALUE	
	Class 1-4 acres (ha)	Class 5 acres (ha)	Total acres (ha)			Total (Dollars)	Per Acre Irrigated (Dollars) (per ha irrigated)
Full Irrigation Service							
Elephant Butte Irrigation District (New Mexico)	90,640 (36,709)	11,442 (4,634)	102,082 (41,343)	102,082 (41,343)	85,380 (34,579)	40,850,901 (16,544,615)	$ 478.46 ($1176.44)
El Paso County Water Improvement District No. 1 (Texas)	69,010 (27,949)	7,104 (2,877)	76,114 (30,826)	76,114 (30,826)	52,897 (21,423)	18,405,331 (7,454,159)	$ 347.95 ($ 659.14)
SUBTOTAL-Full	159,650 (64,658)	18,546 (7,511)	178,196 (72,169)	178,196 (72,169)	138,277 (56,002)	59,256,232 (23,998,774)	$ 428.53 ($1058.10)
Supplemental Irrigation Service							
Hudspeth County Conservation and Reclamation District No. 1 (Texas)	18,342 (7,429)	0 (0)	18,342 (7,429)	18,342 (7,429)	12,446 (5,041)	3,153,392 (1,277,124)	$ 253.37 ($ 625.60)
SUBTOTAL-Supplemental	18,342 (7,429)	0 (0)	18,342 (7,429)	18,342 (7,429)	12,446 (5,041)	3,153,392 (1,277,124)	$ 253.37 ($ 625.60)
TOTAL	177,992 (72,087)	18,546 (7,511)	196,538 (79,598)	196,538 (76,598)	150,723 (61,043)	62,409,624 (25,275,898)	$ 414.07 ($1022.40)
Total Previous Year	177,992 (72,087)	18,546 (7,511)	196,538 (79,598)	196,538 (76,598)	148,270 (60,049)	59,410,412 (24,061,216)	$ 369.78 ($ 913.04)

* Annual Report, Rio Grande Project, U.S. Bureau of Reclamation.

TABLE 4. WATER USERS, IRRIGABLE AREAS AND POPULATION, RIO GRANDE PROJECT AND HUDSPETH IRRIGATION DISTRICT, 1974.*

Irrigation Users	Data Card	Number of Farms	Irrigable Acres (ha)	Acre-Feet (ha-m) of Water Delivered	Population	ADP Code CC80
Full-Time Farms						
Full Irrigation Service	6-24	2,024	159,635 (64,652)		9,612	
Supplemental Irrigation Service	25-43	75	18,342 (7,429)			
Temporary Irrigation Service	44-62					2
Part-Time Farms						
Full Irrigation Service	6-24	2,588	13,076 (5,296)		7,847	
Supplemental Irrigation Service	25-43					
Temporary Irrigation Service	44-62					3
Urban, Suburban & Industrial Lands						
Full Irrigation Service	11-24		5,485 (2,221)		31,995	
Supplemental Irrigation Service	30-43					
Temporary Irrigation Service	49-62					4
Municipal and Industrial Users						
M&I Prime Contracting						
City of El Paso, Texas	6-21	16		13,291 (1,639)	350,000	5

* Annual Report, Rio Grande Project, U.S. Bureau of Reclamation.

1985 time period are that El Paso will grow at a rate of about 78 percent, to a population of 611,820, while the population of Las Cruces will be greater than 65,000 in 1990. This does not include Juarez which may have a population of one million by 1985. The total regional population of El Paso County, Dona Ana County and Juarez could be around two million by 1985, compared to the approximately 865,000 in 1970. Urbanization is not an important consideration north of Las Cruces but it is affecting land and water use in areas along the river below Las Cruces and around El Paso.

The counties in the study area are growing fairly rapidly with Hudspeth County proving the exception (Appendix A). The rural areas are losing population. For the most part, people either live in urban areas or towns with less than 2,500 people. Towns that have populations of 1,000-2,500 are not prevalent.

Of significance to land use in the Valley are the characteristics of the rural nonfarm and the rural farm populations, plus the qualities of the farms they operate. The rural farm population is defined by the U.S. Census as residents living on a place of ten acres or more from which sales of farm products of the preceding year amount to $50 or more, or a place less than ten acres from which sales of farm products of the preceding year amount to $250 or more. In short, this definition distinguishes a population that utilizes the land for farming from one that simply lives on several acres of land.

This rural nonfarm population has a level of formal education similar to the rural farm population, with the exception of El Paso County where it is significantly lower. The median income and the per capita income of the rural nonfarm population is significantly lower than the rural farm population, with El Paso County having the highest rural farm median and per capita income. Sierra County has the lowest rural farm median income, while Dona Dna has the lowest rural farm per capita income. Given the above situation and the different levels of a rural farm and rural nonfarm population in the four counties, there should be different responses to any particular innovation.

A second influential characteristic is farm ownership (Appendix A). The most prevalent form of ownership of a farm unit is the individual or family type. These are more numerous and they occupy more land in the Valley. Partnerships and corporations are important in terms of acreage occupies. In the four-county area they occupy as much land as family owned farms, though they are much less numerous.

Another aspect of farm ownership is the tenure of the operator. Tenure of the operator has been defined by the Census as: 1) full owners--who operate only the land they own; 2) part owners--who operate land they own and also land they rent from others; 3) tenants--who operate land they rent from others, or work on shares for others. Full owners outnumber the other classes, but part owners operate more acres than other classes (Appendix A). These people can be part-time farmers, farmers renting land from other retired or elderly farmers, or they can be managers of other farms. The diversity of farmers and farm operations in the Valley will make response to innovation variable. Capacities to absorb changes in land and water use will vary and make water quality improvement problematic.

Physical qualities of farms affect ownership and operation and the response to recommended or required changes in land and water use. A small percentage of the total farm land area in the counties is irrigated, but a large number of the farms do have portions of their land irrigated, from 59 percent in Sierra County to 82 percent in Dona Ana County (Appendix A). A majority of the irrigated farm units are small--less than 100 acres in size. Yet the significant acreage of irrigated land is in units that range in size from 260-1,000 acres (105-405 ha) (Appendix A). Thus, there are at least two distinct types of farm operators who are to examine any specific type of innovation, i.e., the large, commercial farm operator who may be a partner or corporate member, and the operator of a smaller, family unit. Their circumstances are probably quite different and their response to change variable.

Corresponding to size and providing measures of productivity are the categories of economic class. Class is determined by amounts of product sales. Generally, the larger the farm, the larger the annual sales. But, in the Valley the amount of irrigated land is significant to sales. In Dona Ana and El Paso Counties, there are large numbers of part-time operations. Otherwise, there are significant numbers in all classes--$2,500 to $80,000 and up. The wide distribution of farms by economic class will also tend to make response to change variable.

In summary, there is a rapid urbanization process that will be playing in the future a more central role in any water quality program. The rural areas have a large percentage of rural, nonfarm residents, while the rural farm areas have a large number of independent family-farm units. The irrigated acreage is somewhat concentrated on farms that range in size from 260-1,000 acres (105-405 ha). All of these factors detail the type of population that will be introduced to any new water quality program and the type of population that must be taken into consideration in implementing any program.

Institutional Setting

There exists in the project area an institutional structure that has evolved to provide and protect rights to water supplies, to provide for distribution of irrigation water, and to manage the use of water in agriculture. This structure is illustrated in Figure 2. Organizations involved are the following:

Federal: International Boundary and Water Commission
U.S. Bureau of Reclamation
U.S. Geological Survey
Environmental Protection Agency

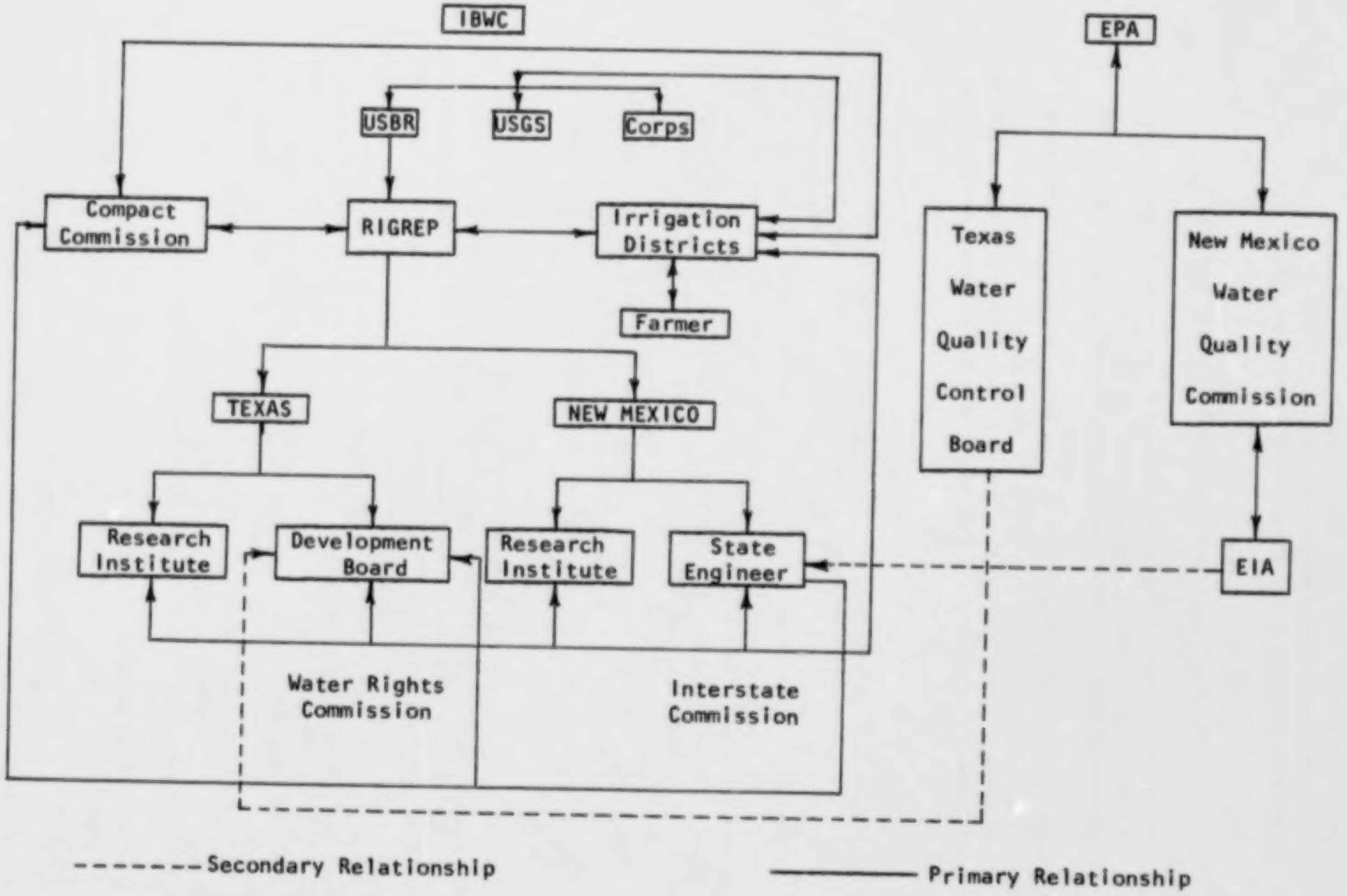

IBWC
EPA
USBR
USGS
Corps
Compact Commission
RIGREP
Irrigation Districts
Farmer
Texas Water Quality Control Board
New Mexico Water Quality Commission
TEXAS
NEW MEXICO
Research Institute
Development Board
Research Institute
State Engineer
EIA
Water Rights Commission
Interstate Commission
------Secondary Relationship
——— Primary Relationship

Figure 2. Institutional structure, Rio Grande Project, New Mexico.

State:	State Engineer Water Quality Control Commission Environmental Improvement Agency New Mexico and Texas Water Resources Institutes
Regional:	Rio Grande Compact Commission Rio Grande Regional Environmental Project (RIGREP)
Local:	Elephant Butte Irrigation District El Paso Water Improvement District No. 1 Hudspeth County Conservation and Reclamation District No. 1

It is through this institutional structure that proposals for change in water allocation, distribution and use must be processed. The interests and concerns of water managers and users will be expressed through the organizations. Implementation of change will depend on organizational approval to a large extent.

Irrigation Districts--

Irrigation districts are organizational entities that are formed by farmers in order to meet their respective water needs, and therefore, are the organizations that most directly reflect farmers' interests. The districts, through the guidance of a board of directors, have the power to construct, purchase, or otherwise secure canals, ditches, reservoir sites, water rights, and rights-of-way necessary for the purpose of the district, and to maintain and operate them. In times when the quantity of water is low, the district can establish an allotment system of water delivery as long as no diversion occurs that is to the detriment of those having prior rights to the use of the water in question. The portion of the Rio Grande River that is under study has three such districts: Elephant Butte Irrigation District, El Paso Water Improvement District No. 1, and Hudspeth County Conservation and Reclamation District No. 1.

The Elephant Butte District (EBID) is a modern, dynamic organization which has the resource potential for initiating many types of changes in distributional facilities and water management practices. It has initiated some actions to control discharges of effluent into its system and into the river, because there is concern about the purity of water used to irrigate crops. The manager and board of directors have proposed a one-hundred million dollar modernization plan involving canal lining and installation of underground pipe. The project will reduce seepage losses from conveyance facilities and thus increase water available for irrigation of crops. The district includes some of the best land in the Valley, its water rights are secure, and its water supply comes directly from Elephant Butte Reservoir. It is, therefore, a significant factor in water supply management in the Valley--one to be reckoned with when changes are proposed.

The Hudspeth District is a district that has no water rights, is underdeveloped in terms of storage and conveyance facilities, and is underfinanced in its on-going operations. Located at the lower end of the project area, it has access only to return flows from lands above it, plus runoff from infrequent storms. The quality of water is sufficiently poor that crop alternatives are limited. Since the 1950's, the acreage (hectares) irrigated has dropped from 18,000 (7,290 ha) to about 10,000 (4,050 ha). The degree of involvement in water management policy of the Valley is quite different from the other two districts. As an "independent" district, the emphasis by the members is on solving its own problems, and the district has not to this point sought much outside support in the alleviation of its problems of water quality and water management in agriculture.

Between these two districts lies the El Paso Water Improvement District. It actually extends into New Mexico, but most of the irrigated lands are in the Valley, below El Paso. Water is diverted from the river at El Paso and conveyed to farms within the district. A problem of management is created by "creeping urbanization" of lands near the city. While some water is diverted away from subdivided areas to eligible lands, other water stays in the subdivided areas to be used on hobby farms, gardens, etc. Quality of the river water is poorer than that available to the farmers in the Elephant Butte district and there are some limits on crop alternatives. The district is well organized and managed, is usually involved in an improvement project, and cooperates as an "equal partner" in policy decisions affecting water in the Valley.

Regional Organizations--

The study area is in many ways an isolated region set apart from the surrounding environment. It is a separate physiographic, economic and social entity that in many respects is well integrated and independent of political and economic forces in New Mexico and Texas. Two organizations that directly reflect a regional orientation are the Rio Grande Compact Commission and the Rio Grande Regional Environmental Project (RIGREP).

The Rio Grande Compact Commission is made up of representatives from the participating compact states of Colorado, New Mexico and Texas. The Compact defines a water management system which secures the negotiated interstate use of the Rio Grande River. The Commission is authorized to enforce the provisions of the Compact. Administration of the Compact encompasses the following issues: quantity of water, flood control structures, the effect of urbanization and the subsequent definition of water rights and agricultural land, and the Indian and Mexican water rights. With regard to the quality of water, the Compact is almost totally silent.

Out of the efforts of some private individuals who were concerned about the future of the region, the Rio Grande Regional Environmental Project (RIGREP) emerged. The purpose of the project is to prepare a plan and program for the management of the water and related land and natural environmental resources that will:

a. enable the Rio Grande Valley region to contribute more substantially to the national wealth and well-being through expanded development of all its resources within proper environmental constraints;

b. foster improvement in the economic well-being of the citizens of the region through expanded regional development within proper environmental constraints;

c. protect and enhance the natural environmental resources for the benefit of the citizens of the region, the state and the Nation; and

d. improve the quality of life, environmentally and socially, of the citizens of the region.

The project leadership involves an executive committee which exercises overall project direction and a policy committee that provides the means in which the full degree of input can be exploited for research and study. The executive committee involves representatives from the Bureau of Reclamation, the city of Las Cruces, Elephant Butte Irrigation District, El Paso County Water Improvement District, Greater Agricultural Income Now (GAIN), Governor's Planning Office-Texas, Governor's Energy Projects Office-New Mexico, Hudspeth County Conservation District, New Mexico State Engineer, New Mexico Water Resources Research Institute, Public Service Board of El Paso, Rio Grande Compact Commission-Texas, Texas Water Development Board, and the Texas Water Resources Institute. This committee is supplemented by a Policy Committee of some sixty members representing all involved governmental entities, economic sectors, universities and interested citizens. This project has intensive linkages to the political organizations of both New Mexico and Texas and has built up a very influential regional organization that deals with activities covering the whole spectrum of regional life.

State Agencies--

There exists a plethora of state organizations that are involved in some way in the administration of water resources. For New Mexico, the crucial ones are the State Engineer, the New Mexico Water Resources Research Institute, the Interstate Stream Commission, and the Water Quality Control Commission/ Environmental Improvement Agency (EIA). The significant organizations for Texas are the Texas Water Development Board, the Texas Water Resources Research Institute, the Texas Water Quality Board, and the Texas Water Rights Commission.

Knowledge of the resource situation is accumulated by the respective research institutions. This knowledge is used for planning and program purposes by the State Engineer for New Mexico and the Texas Water Development Board. In New Mexico, the State Engineer is also the secretary of the Interstate Stream Commission. This Commission negotiates compacts with other states to settle interstate controversies or to make equitable distribution and diversion of waters in interstate stream systems. The Commission is responsible for the negotiation of any amendment to these compacts and for interpretation necessary to the administration of the compacts. Another major function of the Commission is to review and comment on plans for federal water projects in New Mexico and on interstate streams in other states to make sure that New Mexico's interests are protected. This includes cooperation in and coordination of the work of federal agencies in planning projects in New Mexico.

The agencies that carry out the functions prescribed by the Federal Water Pollution Control Act of 1972 are the New Mexico Water Quality Control Commission and the Texas Water Quality Board. In New Mexico, the major burden of water pollution control falls on the Environmental Improvement Agency (EIA), one of the organizations making up the Control Commission. Standards have been set on the Rio Grande River by both states. However, significant problems have been associated with stream quality: 1) the New Mexico and Texas standards do not generally coincide; 2) an adequate monitoring system is not being maintained; and 3) inadequate efforts are currently being made to determine the effects of present and proposed developments in the region on stream quality. The states agencies' actions with regard to the Rio Grande must fall within the prescribed parameters of use delineated by the Compact.

Federal Agencies--

Four federal entities play important roles in the development, management and operation of the Rio Grande River system: The Bureau of Reclamation (USBR), the United States Geological Survey (USGS), the International Boundary and Water Commission (IBWC), and the Environmental Protection Agency (EPA). The USBR provides for the storage, diversion and development of water for the reclamation of arid and semi-arid lands. Its responsibilities have expanded to hydroelectric power production and recreation exploitation of its facilities. The operation and maintenance of the irrigation facilities it constructed is achieved on a cooperative business basis with the local water users' districts.

Location, classification and monitoring of use of water resources are responsibilities of the U.S. Geological Survey. It conducts studies with regard to quantity, quality, distribution, movement, and availability of surface and ground water. It also evaluates requirements for industrial, domestic and agricultural purposes in river basin and ground water provinces and determines the quality of such water.

The International Boundary and Water Commission oversees the Treaty of 1906 with Mexico, which provides for a diversion from the Rio Grande at El Paso of 60,000 acre-feet (7,398 ha-m). It administers also a 1944 treaty concerned with control of the river below Fort Quitman. The treaties have not dealt with the quality of water, but the quality issue is obviously important to both countries. Increasing urbanization in the El Paso/Juarez area is a problem of the commission as it administers water resources of the Rio Grande.

Two other agencies whose work could be of greater importance in the future for the study are the Corps of Engineers and the Bureau of Indian Affairs (BIA). The Corps is responsible for the construction, operation and maintenance of improvements on rivers, including flood control, protection of navigability, water supply, and river flow regulations among others. The BIA is involved with Indian land and waters which are necessary to the agriculture on the reservations.

LEGAL CHARACTERISTICS

The Rio Grande River Basin, and in particular the portion of the Basin included in the project area, presents an excellent illustration of legal complexities, evolved impediments and "self-interest" efforts to resolve particular issues. There is a wide range of legal and organizational structures within the temporal, spatial and jurisdictional parameters of the water supply, the developments associated with it and the technical attributes of the resource. The evaluation of these laws and organizations is a fascinating study of the differences in practices and the creation of endogenous solutions.

Historically, the present legal system has been influenced by the Spanish water law system, the common law riparian system of England, the political decision made in creating Indian reservations, and the doctrine of prior appropriation.

The laws and administrative machinery also grew along political boundaries within the region. Each state (New Mexico and Texas) adopted its own system of water law for surface and ground water, and they developed separate water quality administrations. The result is a significant degree of conflict in administration in the same hydrologic unit due to the lack of uniformity and consistency in the controlling legislation. The Federal Government has adopted a body of law in both water quantity (reservation doctrine and water rights held by federal agencies) and water quality. Due to the interstate and international characteristics of the Rio Grande River, compact and treaty law has developed, adding additional layers of jurisdiction.

In the next section is a discussion of the various aspects of the law of water resources as they impact on water use in the study area.

Historical Development

Indian--

Indian water rights are based on the idea that Indians have reserved to them, not only the land of their reservations, but also the right to use enough water to irrigate any irrigable portions (Act of March 3, 1909, ch 263, 35 Stat. 812, Winters vs United States, 207 U.S. 564, 28 Sup. Ct. 107, 1908). In Arizona vs California (373 U.S. 546, 82 S. Ct. 1468, 1963), the Supreme Court held that the quantity of water reserved for Indian Reservations is measured by potential use of lands within the reservation for irrigation and the water requirements of adapted crops. In Skeem vs United States (273 Fed. 93, C.A.-9 Idaho, 1921), the court held that the quantities of water reserved for the use of the Indians on the reservations were the amounts necessary to irrigate all of the reservations susceptible of irrigation, regardless of whether the Indians had actually placed those lands under cultivation and irrigation.

The priority of an Indian water right dates from the time the reservation was set aside for Indian use. Although no Indian reservations exist in the project area, the impact from potential upstream allocations through the exercise of the doctrine can be substantial.

Spanish--

New Mexico--"The right to appropriate and use water for irrigation has been recognized longer than history...evidences of it are found all over Arizona and New Mexico in the ancient canals of prehistoric people" (Clough vs Wing, 2 Ariz. 371, 17 P. 453, 1888). "The community irrigating ditch or acequia is an institution peculiar to the native people living in that portion of the Southwest which was acquired by the United States from Mexico" (Snow vs Abalos, 18 N.M. 681, 691, 140 P. 1044, 1914).

Long before American occupation of New Mexico in 1846, large areas of Spanish land grants existed in which the colonizers, or settlers, shared "common lands and waters" (see Ch. 8, N.M. Stat. Ann., 1953). The Spaniards brought with them the technology and institutional framework for irrigation of land and the distribution of water. Their customs and techniques derived from a prior diffusion of near eastern culture which had been introduced into Spain by the Muslims in the early middle ages (The Old World Background of the Irrigation System of San Antonio, Texas--Thomas F. Glick, 1972). Whether irrigation companies were autonomously administered or controlled by a town government, or the water was considered public or private, attached to the land or alienable, actual practice was based upon the following: 1) the irrigators of one canal received their water in proportion to the amount of land irrigated; 2) administration was entrusted to officials, usually the irrigators. Thus, irrigators had substantial power in regulating their own systems (Ibid., p. 4).

The present water law of New Mexico protects these early water rigths (75-8-1). Early legislation (N.M. Stat. Ann., 75-14-3, 4, 6, 9, 27 to 31, 1953) provided that ditches or acequias already established should not be disturbed; that all rivers and streams thereto known as public ditches were officially declared to be such; and that all inhabitants should have the right to construct private or common acequias and take the water from them with the understanding that they should pay the owner over whose lands the acequias passed.

Texas--In Miller vs Letzerich (121 Tex. 248, 49 S.W. 2d 404, 1932), the Texas Supreme Court held that a change of sovereignty did not affect the property rights of the inhabitants of the territory involved. The laws of Mexico in effect when Mexican grants were made were held to be controlling in determining the rights of holders of title thereunder (Manny vs Robinson, 122 Tex. 213, 56 S.W. 2d 438, 1932; Luttes vs State, 324 S.W. 2d 167, Tex., 1939).

Statutes in force in the Republic of Texas before the introduction of the common law are to be construed in the light of Mexican law, and the validity and legal effect of contracts and of grants of land made before the common law was adopted must be determined according to the civil law in effect at the time of the grants (Miller vs Letzerich, supra at 121). Therefore, whatever title rights and privileges inhabitants of Texas received from the Spanish or Mexican governments remain intact even with the change in sovereignty and adoption of the common law.

In Turner vs Big Lake Oil Co. (128 Tex. 155, 96 S.W. 2d 221, 1936), the court held that the rights of grantees of lands granted by Spain or Mexico extend to the use of diffused surface waters collecting on their lands and such rights could not be divested by provisions within the state's water appropriation statute which declares storm, flood or rainwaters to be the property of the state subject to appropriation.

Endogenous Systems--New Mexico and Texas, although neighboring states with a common river, adopted water laws significantly different. New Mexico adopted the doctrine of prior appropriation for its surface and ground waters. Texas, on the other hand, created a dual system involving the riparian and prior appropriation doctrines for surface water rights, and the absolute ownership rule for ground waters. The development of these laws is hereafter described.

State Water Laws--New Mexico

Water Quantity Law--

Early territorial legislation established the appropriation doctrine in New Mexico (Hutchins, The New Mexico Law of Water Rights, 1955). The territorial supreme court in 1898 ruled that the law of prior appropriation existed under the Mexican Republic at the time of the acquisition of New Mexico and was the settled law of the territory (United States vs Rio Grande Dam and Irrigation Co., 9 N.M. 292, 51 P. 674, 1898).

The constitution recognizes all existing rights to the use of water for any beneficial purposes, declares that unappropriated water of every stream belongs to the public subject to appropriation, and states that beneficial use is the basis, the measure and the limit of the right to use water (New Mexico Const., Art. XVI). The law not only includes surface water but also ground waters which are defined as ground water in underground streams, channels, artesian basins, reservoirs, or lakes having reasonably ascertainable boundaries (New Mexico Stat., Sec. 75-11-1).

In 1907, a comprehensive statute was enacted to govern the appropriation of waters from a watercourse. This law, amended in part, still governs the appropriation of water (Sec. 75-5-1 to 37) and is the exclusive procedure to acquire such a right (Farmer's Development Co. vs Rayaldo Land and Irr. Co., 28 N.M. 357, 213 P. 202, 1923). A watercourse is defined as any river, creek, arroya, canyon, draw, or wash, or any other channel having definite ranks and bed with visible evidence of the occasional flow of water (Sec. 75-1-1). The flow of water need not be continuous for a channel to constitute a watercourse (Jaquez Ditch Co. vs Garcia, 17 N.M. 160, 124 P. 891, 1912).

An application to appropriate must be filed with the State Engineer for some recognized beneficial purpose (Sec. 75-5-1). The State Engineer must find that there is unappropriated water available in the source before the application is approved (Sec. 75-5-5). He may refuse to grant an application for surface water if it would be contrary to the public interest (Ibid.). In Young and Norton vs Henderlider (15 N.M. 666, 110 P. 1045, 1910), the court held that matters of public interest went beyond questions of whether the project was dangerous to public health or safety, and encompass an evaluation of all facts and circumstances surrounding competing proposals for water use in order to determine which proposal better serves the public interest. An application may be approved for a lesser quantity than applied for (Sec. 75-5-5).

If the application is approved, the applicant is provided a permit and given a certain time within which to construct his works and place the water to a beneficial use. Once the project is completed, the State Engineer issues a license for the right to use that amount of water which has been put to a beneficial use (Sec. 75-5-12). Any user aggrieved by a decision of the State Engineer can appeal to the district court (Sec. 75-5-1 to 3).

Water used for irrigation purposes is considered appurtenant to the land upon which it is used, but this water right can be severed from the land and transferred to other land and for other purposes (Sec. 75-5-21, 75-5-22). To accomplish a change, a change application must be submitted with the State Engineer and notice of the proposed change must be given by publication (Sec. 75-5-22, 23). In order to approve a change application, the State Engineer must find that such a change can be made without causing a detriment to other valid existing rights on the stream (Sec. 75-5-23).

Water may be delivered into any ditch, stream, or watercourse to supply appropriators therefrom. In an exchange, an equivalent quantity of water may be taken either above or below the point of delivery, less a proper deduction for evaporation and seepage so long as other rights are not injured by the exchange (Sec. 75-5-24).

When the owner of a water right fails to beneficially use all or any part of his right for a period of four years, and has had one year written notice from the State Engineer, the unused water reverts to the public and is considered unappropriated public water (Sec. 75-5-26 and 75-11-8). This forfeiture provision attempts to promote maximum use of the state's water resources.

In Pioneer Irrigation Ditch Co. vs Bashek (41 N.M. 99, 64 P. 2d 388, 1937), the court held that no right could be acquired by adverse possession. Subsequent decisions seem to support this position (Martinez vs Mundy, 61 N.M. 87, 295 P2d 209, 1956).

In Walker vs New Mexico and S.P.R.R. (165 U.S. 593, 1897), the court held that a landowner has the right to capture and use diffused surface waters.

As to the disposal of diffused surface water, an upper owner may not artificially collect diffused surface water and discharge it onto his lower neighbor in a manner that would do injury (Martinez vs Cook, 56 N.M. 343, 244 P2d 134, 1952).

All underground waters belong to the public and are subject to appropriation for beneficial use (Sec. 75-11-19). No permit or license to appropriate is required unless the appropriation is within a basin declared by the State Engineer (Sec. 75-11-2). Anyone intending to appropriate ground water in a declared basin for irrigation or industrial use must make application to the State Engineer for a permit. Beneficial use is the basis, the measure and the limit to the right to use ground water (Sec. 75-11-2, 3). The same rules for change of use and forfeiture of surface water apply to ground water rights (Sec. 75-11-7, 8).

The water right is a real property right (New Mexico Products Co. vs New Mexico Power Co., 42 N.M. 311, 77 P2d 634, 1938), granting the holder permission to use the public resources according to the terms of the license (Snow vs Abalos, 18 N.M. 681, 140 P. 1044, 1914). An appropriator's right cannot be measured by the capacity of his ditch, but is measured by the quantity of water which has been applied to a beneficial use (Harkey vs Smith, 31 N.M. 521, 247 P. 550, 1926). When an increased supply is developed, the developer is entitled to the increased flow (Ibid.). An appropriator cannot waste water, but is entitled to his beneficial use requirements (Snow vs Abalos, 18 N.M. 681, 140 P. 1044, 1914).

The State Engineer can allow only that amount of water to be diverted that is consistent with good agricultural practices and will result in the most effective use of available water (Sec. 75-5-17). This is an important distinction in New Mexico law as it provides a dynamic feature in the exercise of administrative authority and a correspondingly higher duty requirement in the implementation of the state's public trust.

The right of a junior appropriator is subservient to prior rights and can only be exercised after prior rights are fully satisfied. The senior appropriator is not entitled to more water than he can beneficially use, and junior appropriators are entitled to use any excess to fill their entitlements (State ex rel. Community Ditches vs Tularosa Community Ditch, 19 N.M. 352, 143 P. 207, 1914). An upstream junior appropriator is not liable to a downstream senior appropriator for shortages absent a demand on the State Engineer by the senior appropriator for the enforcement of priorities (Warley vs United States Borax and Chemical Corp., 78 N.M. 112, 428 P.2d 651, 1967). An owner of an irrigation right need not use his water in such a way that no irrigation runoff reaches lower lands, but he is liable for injuries willfully or negligently inflicted by unnecessary uses of the water (Stroup vs Frank A. Hubbel Co., 27 N.M. 25, 192 P. 519, 1920).

Water Quality Law--

The Water Quality Control Commission is composed of the Director of the Environmental Improvement Agency, the Director of the New Mexico Department of Game and Fish, the State Engineer, the Secretary of the Oil Conservation Commission, the Director of the State Park and Recreation Commission, the Director of the Department of Agriculture, the Executive Secretary of the State Natural Resource Conservation Commission, the Director of the Bureau of Mines, and a representative of the public (N.M. Stat. Ann. Sec. 75-39-3, 1953).

The Commission must adopt a comprehensive water quality program (Ibid., Sec. 75-39-4 B), water quality standards (Ibid., Sec. 75-39-4 C), and publish regulations to prevent or abate water pollution (Ibid., 75-39-4 D). It can also require persons to obtain permits for the discharge of any water contaminant either directly or indirectly into the water (Ibid., Sec. 75-39-4.1). New Mexico has not yet adopted a permit program called for in the Federal Water Pollution Control Act of 1972, and thus EPA must implement the NPDES program.

State Water Laws--Texas

Water Quantity Law--Texas

Texas is classified as having a dual system of prior appropriation and riparian rights. Presently, however, the appropriation rights have the greater importance. After July 1, 1895, riparian rights in the owner of any lands are not recognized by the state of Texas. "This code does not recognize any riparian right in the owner of any land the title to which passed out of the State of Texas after July 1, 1895" (Vernons Texas Code Annotated Water, 1972, 5.001).

The evaluation of water law in Texas is complex. Many controversies over land grants of the 18th and 19th centuries from Spain and Mexico along the Lower Rio Grande arose over the existence of riparian rights. A case decided in 1961 held that these grants did not include appurtenant irrigation rights (Texas vs Valmont Plantations, 346 S.W. 2d 853, Tex. Civ. App., 1961). This court concluded that no evidence existed concerning customary riparian rights for irrigation in the civil law governing navigable streams in those countries. Irrigation rights, therefore, must rest on specific grants from the sovereign.

Specific irrigation grants were made by Mexico even after 1836 when Texas acquired its independence. Civil law reigned in the Republic of Texas between 1836 and 1840.

The common law of England was adopted by Texas in 1840. This introduced riparian law which continued from 1845 until 1889. At this time, the appropriation system was introduced but it was limited to the arid portions of Texas (The Irrigation Act of 1889, Tex. Gen. Law, 1889, ch. 88, p. 100). This latter doctrine provided that appropriators could obtain water rights by diversion and application of that water to a beneficial use. Appropriators were required to file affidavits and maps which illustrated and described the diversion works and the proposed use with the county clerk.

Public waters were divided into two categories by amendments to the law made in 1895 (Tex. Gen. Law, 1895, ch 21, p. 21). These were "ordinary flow and underflow" and "storm or rain waters." Riparian rights could only attach to ordinary flow and underflow waters. Forfeiture did not occur even if the appropriators failed to file. Perfection of the right occurred when the works were completed and the water diverted. The appropriator had to file an affidavit which showed the approximate number of acres to be irrigated, the name, size, capacity and location of the ditch, the appropriator's name and the stream from which the water was to be diverted.

The Burgess Classock Act of 1913 (Tex. Gen. Law, 1913, ch 171, p. 358) was the first appropriation act to have a statewide application. Under this Act, county clerks were given a specific time within which to file certified copies of all instruments which related to appropriated waters with the Board of Water Engineers. A permit system was then introduced which superseded the county clerk filing procedure.

In 1917, the Canales Act (Tex. Gen. Laws, 1917, ch. 88, p. 211) changed and enlarged the Burgess-Classock Act. The permit system was retained and is still in use today. A procedural aspect for adjudicating water rights was declared unconstitutional on the grounds that judicial functions were unlawfully delegated to an administrative agency (Board of Water Engineers vs McKnight, 111 Texas 82, 229, S.W. 301, 1921).

Applications to appropriate normal flow water in Texas streams have been regularly required since 1948 due to the fact that most rivers have been fully appropriated

In Texas, under the current law, as between appropriators, the first in time is the first in right (Sec. 5.027). Section 5.021 provides that the water of the ordinary flow, underflow and tides of every flowing river, natural stream and lake, and of every bay or arm of the Gulf of Mexico and the storm water, flood water and rain water of every river,natural stream, canyon, ravine, depression, and watershed in the state is the property of the state. This statute further states that, water which is imported from any source outside the boundaries of the state for use in the state and which is transported through the beds and banks of any navigable stream within the state or by utilizing any facilities owned or operated by the state is the property of the state (Sec. 5.021(a) and (b)).

Section 5.022 further provides that the right to the use of state water may be acquired by appropriation in the manner and for the purposes provided in this chapter. When the right to use state water is lawfully acquired, it may be taken or diverted from its natural channel. It was stated in South Texas Water Co. vs Bieri (Civ. App. 1952, 247 S.W. 2d 268) that the waters of public streams belong to the sovereign and are held by the sovereign in trust for the public.

In Texas, diffused surface waters may be impounded without regard to a downstream user of the requirement of obtaining a permit.

> The water of the ordinary flow, underflow and tides of every flowing river, natural stream, and lake, and of every bay or arm of the Gulf of Mexico, and the storm water, floodwater, and rain water of every river, natural stream, canyon, ravine, depression, and watershed in the state is the property of the state (5.021(a)).

In Turner vs Big Lake Oil Co. (128 Texas 115, 96 S.W. 2d 221, 1936), the Texas Supreme Court held that to the extent that the above statute purported to convert diffused surface water into public waters on lands patented before 1913, it was unconstitutional. Texas takes the position that the landowner has property rights in diffused surface water under the "civil law" rule (Sec. 5.040).

The exclusive method for acquiring an appropriation right is under the permit system. Section 5.123 requires that:

(a) An application to appropriate unappropriated state water must:
  (1) be in writing and sworn to;
  (2) contain the name and post office address of the applicant;
  (3) identify the source of water supply;
  (4) state the nature and purposes of the proposed use and the amount of water to be used for each purpose;
  (5) state the location and describe the proposed facilities;
  (6) state the time within which the proposed construction is to begin; and
  (7) state the time required for the application of water to the proposed use.

(b) If the proposed use is irrigation, the application must also contain:
  (1) a description of the land proposed to be irrigated; and
  (2) an estimate of the total acreage to be irrigated.

(c) If the application is for a seasonal permit, under the provisions of Section 5.136 of this code, the application must also state the months or seasons of the year the water is to be used.

(d) If the application is for a temporary permit, under the provisions of Section 5.137 of this code, the application must also state the period of the proposed temporary use.

A permit to appropriate water gives the appropriator no title to the water, but rather the right of one to divert and use that amount of water which can be beneficially used (Sec. 5.002). Beneficial use is defined as the amount of water which is economically necessary for a purpose authorized by this chapter when reasonable intelligence and reasonable diligence are used in applying the water to that purpose (Sec. 5.025). Section 5.023 lists the purposes for which water may be appropriated and states that water may also be stored or diverted for any other beneficial use.

> A right to use state water under a permit or a certified filing is limited not only to the amount specifically appropriated, but also to the amount which is being or can be beneficially used for the purpose specified in the appropriation and all water not so used is considered not appropriated (Sec. 5.027).

Thus, beneficial use is the basis, the measure and the limit of the right to use water and priority in time confers a prior right (Sec. 5.024).

A system of preferences between types of uses exists when the uses conflict (Sup. 1971, 464 S.W. 2d 268). First priority goes to domestic and municipal uses, followed by industrial uses, irrigation, mining, hydroelectric power, navigation, recreation and pleasure, and other beneficial uses. However, water is allocated according to priority unless a preferred user brings the necessary action.

An appropriator is limited to the quantity of water specified in his permit to a beneficial use; the unused water is subject to the provision of the forfeiture statute.

In Texas Water Rights Commission vs Wright (Sup. 1971, 464 S.W. 2d 268), the court held that water permits owners are not vested with the right of non-use and at all relevant times the state has the rights as the owner of the water. The right which one obtains by a permit for appropriated waters is limited to beneficial and nonwasteful uses. The court stated further that a workable system to regulate the appropriation of waters produced the rule that the beneficial use of waters is the conservation of that resource. The duty to use the water beneficially is inherently attached to a permit to appropriate waters. Therefore, the nonuse of appropriated waters is the equivalent of waste. Although a matured appropriation right to water is a vested right, that right is limited to beneficial and nonwasteful uses (Ibid.).

Water rights can be lost by abandonment or forfeiture. Revocation of a permit occurs upon ten consecutive years of nonuse. This raises a presumption of abandonment of use. Section 5.173 provides that: If no part of the water authorized to be appropriated under a permit or certified filing has been put to beneficial use at any time during the ten year period immediately preceding the cancellation proceedings authorized by this subchapter, then the appropriation is presumed to have been willfully abandoned, and the permit or certified filing is subject to cancellation in whole.

In Texas Water Rights Commission vs Wright (Sec. 5.030), the Texas Supreme Court upheld the constitutionality of the forfeiture statute on the grounds that, while water rights can be considered as a "vested" property interest, no one has a vested right to nonuse. The court construed this statute as creating a conclusive presumption of abandonment after a period of three years of nonuse.

> If any lawful appropriation or use of state water is willfully abandoned during any three successive years, the right to use the water is forfeited and the water is again subject to appropriation (Sec. 5.301 to .341).

The Water Rights Adjudication Act (Sec. 5.303) permits the adjudication of all water rights outstanding on a stream or segment of the stream. The Act also provides for a system of recording claims of water rights.

The statute covers riparian water rights, claims under the Irrigation Acts of 1889 and 1895 which were not previously filed, special claims under Section 5.151 to impound, divert or use water for other than livestock or domestic purposes, and other claims of water rights other than claims under certified filings or permits.

Under the statute, each claimant must file a statement with the Commission before September 1, 1969, which shows the location and the nature of the water right; the stream from which such right is claimed; the date of the commencement of the works; dates of quantity of use; and other pertinent information (Sec. 5.025).

Texas has no provision dealing with the acquisition of water rights through prescriptive or adverse possession. All appropriation rights must be obtained through the acquisition of a permit from the Texas Water Rights Commission.

Section 5.040 provides that a "permanent water right is an easement and passes with the title of land." The Rules and Regulations of the Texas Water Rights Commission provide for rules governing the transfer of water rights.

> A right to use state water under a permit or a certified filing is limited not only to the amount specifically appropriated but also to the amount which is being or can be beneficially used for the purpose specified in the appropriation, and all water not so used is considered not appropriated (Sec. 21.257).

Couple this provision with Section 5.026 which reads as follows:

> No right to appropriate water is perfected unless the water has been beneficially used for a purpose stated in the original declaration of intention to appropriate water or stated in a permit issued by the commission or one of its predecessors.

Water Quality Laws--

The policy of Texas as to water quality is set forth in Section 21.002, which states that:

> ...it is the policy of the state to maintain the quality of water in the state consistent with public health and enjoyment, the propagation and protection of terrestrial and aquatic life, the operation of existing industries and the economic development of the state...and to require the use of all reasonable methods to implement this policy.

The Texas Water Quality Board is the principal authority in the state on matters relating to the quality of water (Sec. 21.022). It is composed of seven members (Sec. 21.061), and must establish the level of quality and control the quality of water within the state (Sec. 21.062). Section 21.066 gives the Board the power to institute court proceedings to compel compliance with their rules, orders, permits, or other decisions. The Board has the power to set water quality standards (21.088), and to develop comprehensive water quality management plans for various areas of the state (Sec. 21.251).

Unless authorized by the Board, no person can discharge agricultural waste into or adjacent to any water in the state (Green vs Biddle, 8 Wheat 1, 92, 5L. Ed. 547).

Compacts and Treaties--

A compact is an agreement, a contract (Black's Law Dictionary, 4th Edition). This term is usually applied to conventions between nations or sovereign states. A compact is a contract between parties, which creates obligations and rights which are capable of being enforced (34 Stat. 2953).

Rio Grande Compact--

The Rio Grande Compact of 1938 has to do only with the portion of the drainage basin of Rio Grande above Fort Quitman, located about 80 miles southeast of El Paso, Texas. This diversion of the total drainage area of the Rio Grande was adopted in the Treaty of 1906 between the United States and Mexico and has been used consistently since then.

Complaints of water shortages were reported to the Mexican Government in the early 1890's near Juarez across the river from El Paso. Shortages also began to occur along the Rio Grande in the Mesilla and El Paso Valleys. The Mexican Government then filed a claim for damages against the United States stating that the shortages were a result of increased diversions from the river in Colorado and New Mexico. The United States Department of State then began an investigation of the situation through the International Boundary Commission. The result was the embargo of 1896 and the Mexican Treaty of 1906. The embargo was not lifted until May of 1925. In return for relinquishment of all claims for damages, the United States guaranteed to Mexico under the Mexican Treaty "an annual delivery in perpetuality in the Rio Grande at the head of the Mexican Canal near El Paso of 60,000 acre-feet (7,398 ha-m) of water." In order to guarantee the fulfillment of the Mexican Treaty and to develop a reclamation project in the Elephant Butte-Fort Quitman section, the United States authorized the Bureau of Reclamation to build the Elephant Butte Reservoir which was completed in 1916. It occupies the nearby river valley for a distance of approximately 40 miles (64 km) from the San Marcial narrows to Elephant Butte. The section referred to as Elephant Butte-Fort Quitman encompasses the reservoir area and the wide plains and long strips of land next to the river from Elephant Butte to Fort Quitman. Of this distance of 210 miles (338 km), 130 miles (209 km) are above El Paso. This section is a series of valleys which are divided by canyons and narrows. The Rio Grande Project is made up of the valleys of Rincon, Mesilla and the northern half of the El Paso Valley on the Texas side of the river. The Hudspeth County Conservation and Reclamation District is the area which is included in the southern half of the El Paso Valley on the Texas side of the river (National Resources Journal, Vol. 14, No. 2, pp. 164 to 167).

The Rio Grande Compact (41.001-41.009) between Texas, Colorado and New Mexico was entered to apportion the waters of the Rio Grande above Fort Quitman, Texas. Article XI states that:

> New Mexico and Texas agree that upon the effective date of this compact all controversies between said states relative to the quantity or quality of the water of the Rio Grande are composed and settled; however, nothing herein shall be interpreted to prevent recourse by a signatory state to the Supreme Court of the United States for redress should the character or quality of the water, at the point of delivery, be changed hereafter by one signatory state to the injury of another. Nothing herein shall be construed as an admission by any signatory state that the use of water for irrigation causes increase of salinity for which the user is responsible in law (*Ibid*.).

Article X states that it is the policy of all three states to avoid waste of waters and officials charged with duties under the compact to use their "utmost efforts to prevent wastage of waters."

Colorado must deliver water in the Rio Grande at the Colorado-New Mexico state line, measured at Lobatos, in each calendar year and must be 10,000 acre-feet less than the sum of the quantities set forth in Table 5.

Adjustments are made for any change in the location of gaging stations, any new or increased depletion of runoff above inflow index gaging stations, and any transmountain diversions into the drainage basin of the Rio Grande above Lobatos.

New Mexico must deliver water to the Rio Grande at San Marcial, during each calendar year, with exception of July, August and September. The quantity is set forth in Table 6 in the tabulation of relationship, which corresponds to the quantity at the upper index station.

This schedule is subject to later provisions, and adjustments are made for any change in location of gaging stations, depletion after 1929 in New Mexico at any time of the year of the natural runoff at Otowi Bridge, depletion of the runoff during July, August and September of the tributaries between Otowi Bridge and San Marcial, by works constructed after 1937, and any transmountain diversions into the Rio Grande between Lobatos and San Marcial.

International Treaties--A treaty is defined as a compact which is made between two or more independent nations with a view to the public welfare (United States vs Belmont, N.Y. 57 S. Ct. 758). It is an agreement or contract between two or more nations or sovereigns, formally signed by properly authorized commissioners, and solemnly ratified by the several sovereigns or the supreme power of each state (Edye vs Robertson, 5 S. Ct. 247).

There are three agreements between the United States and Mexico which relate to the control and beneficial use of the waters of the Rio Grande.

1. Rio Grande Convention (U.S. Department of the Interior, "Documents on the Use and Control of Waters of Interstate and International Streams--Compacts, Treaties and Adjudication," 1956).

This treaty was entered into by the United States and Mexico to provide for the equitable distribution of the waters of the Rio Grande for irrigation purposes (34 Stat. 293). Upon completion of the dam near Engle, New Mexico, the United States agreed to deliver 60,000 acre-feet (7,398 ha-m) to Mexico, in the bed of the Rio Grande at a point where the head works of the Acequia Madre exist above Juarez, Mexico. The United States assures that a given amount of water will be distributed through the year and in the same proportion as the water supply proposed to be furnished from the irrigation systems in the United States in the area of El Paso, Texas, according to Table 7.

TABLE 5. DISCHARGE OF CONEJOS RIVER AND RIO GRANDE, EXCLUSIVE OF CONEJOS RIVER, COLORADO

Conejos River
[Quantities in Thousands of Acre-Feet]

Conejos Index Supply[1]	Conejos River at Mouths[2]	Conejos Index Supply[1]	Conejos River at Mouths[2]
100 (12.33)*	0 (0.00)*	450 (55.49)	232 (28.61)
150 (18.50)	20 (2.47)	500 (61.65)	278 (34.28)
200 (24.66)	45 (5.55)	550 (67.82)	326 (40.20)
250 (30.83)	75 (9.25)	600 (73.98)	376 (46.36)
300 (36.99)	109 (13.44)	650 (80.15)	426 (52.53)
350 (43.16)	147 (18.13)	700 (86.31)	476 (58.69)
400 (49.32)	188 (23.18)		

* Values in parentheses are thousands of hectare-meters.

Rio Grande Exclusive of Conejos River
[Quantities in Thousands of Acre-Feet]

Rio Grande at Del Norte[3]	Rio Grande at Lobatos less Conejos at Mouths[4]	Rio Grande at Del Norte[3]	Rio Grande at Lobatos less Conejos at Mouths[4]
200 (24.66)*	60 (7.40)*	750 (92.48)	229 (28.24)
250 (30.83)	65 (8.01)	800 (98.64)	257 (31.69)
300 (36.99)	75 (9.25)	850 (104.81)	292 (36.00)
350 (43.16)	86 (10.60)	900 (110.97)	335 (41.31)
400 (49.32)	98 (12.08)	950 (117.14)	380 (46.85)
450 (55.49)	112 (13.81)	1000 (123.30)	430 (53.02)
500 (61.65)	127 (15.66)	1100 (135.63)	510 (62.88)
550 (67.82)	144 (17.76)	1200 (147.96)	640 (78.91)
600 (73.98)	162 (19.97)	1300 (160.29)	740 (91.24)
650 (80.15)	182 (22.44)	1400 (172.62)	840 (103.57)
700 (86.31)	204 (25.15)		

* Values in parentheses in thousand hectare-meters.

Intermediate quantities shall be computed by proportional parts.

[1] Conejos Index Supply is the natural flow of Conejos River at the USGS gaging station near Mogote during the calendar year, plus the natural flow of Los Pinos River at the USGS gaging station near Ortiz and the natural flow of San Antonio River at the USGS gaging station at Ortiz, both during the months of April to October, inclusive.

[2] Conejos River at Mouths is the combined discharge of branches of this river at the USGS gaging stations near Los Sauces during the calendar year.

[3] Rio Grande at Del Norte is the recorded flow of the Rio Grande at the USGS gaging station near Del Norte during the calendar year (measured above all principal points of diversion to San Luis Valley) corrected for the operation of reservoirs constructed after 1937.

[4] Rio Grande at Lobatos less Conejos at Mouths is the total flow of the Rio Grande at the USGS gaging stations near Lobatos, less the discharge of Conejos River at its Mouths, during the calendar year.

TABLE 6. DISCHARGE OF RIO GRANDE AT OTOWI BRIDGE AND ELEPHANT BUTTE RESERVOIR, NEW MEXICO

Effective Supply

[Quantities in Thousands of Acre-Feet (hectare-meters)]

Otowi Index Supply	Elephant Butte Effective Index Supply	Otowi Index Supply	Elephant Butte Effective Index Supply
100 (12)	57 (7)	1600 (197)	1195 (147)
100 (25)	114 (14)	1700 (210)	1295 (160)
300 (37)	171 (21)	1800 (222)	1395 (172)
400 (49)	228 (28)	1900 (234)	1495 (184)
500 (62)	286 (35)	2000 (247)	1595 (197)
600 (74)	345 (43)	3200 (395)	1695 (209)
700 (86)	406 (50)	2200 (271)	1795 (221)
800 (99)	471 (58)	2300 (284)	1895 (234)
900 (111)	452 (67)	2400 (296)	2095 (258)
1000 (123)	621 (77)	2500 (308)	2095 (258)
1100 (136)	707 (87)	2600 (321)	2195 (271)
1200 (148)	800 (99)	2700 (333)	2295 (283)
1300 (160)	897 (111)	2800 (345)	2395 (295)
1400 (173)	996 (123)	2000 (247)	2495 (308)
1500 (185)	1095 (135)	3000 (370)	2595 (320)

TABLE 7. DELIVERY SCHEDULE OF WATER FROM THE UNITED STATES TO MEXICO

Month	Acre-Feet Per Month	Ha-m Per Month	Corresponding Cubic Feet of Water	Cubic Meters
January	0	0	0	0
February	1,090	134	47,480,400	1,343,695
March	5,460	673	237,837,600	6,730,804
April	12,000	1,480	522,720,000	14,792,976
May	12,000	1,480	522,720,000	14,792,976
June	12,000	1,480	522,720,000	14,792,976
July	8,180	1,009	356,320,800	10,083,878
August	4,370	539	190,357,200	5,387,108
September	3,270	403	142,411,200	4,030,237
October	1,090	134	47,480,400	1,343,695
November	540	67	23,522,400	665,684
December	0	0	0	0
TOTAL	60,000	7,399	2,613,570,000	73,964,031

In the event of an extraordinary drought, the amount delivered to the Mexican Canal will be diminished in the same proportion as the water delivered to the lands under irrigation in the United States.

2. Rio Grande Rectification Convention, 1933 (34 Stat. 1295).

This treaty, again between the United States and Mexico, was entered into to alleviate flood dangers and stabilize international boundary lines. The United States agreed to pay 88 percent of the construction costs and the Mexican government 12 percent.

3. Rio Grande, Colorado and Tijuana Treaty, 1944 (59 Stat. 1219).

This treaty between Mexico and the United States was entered into to regulate the use of the waters of the Rio Grande River, Colorado River and the Tijuana River. The International Boundary Commission was established to carry out the principles contained in the Treaty of November 12, 1884.

Article III establishes preferences, with domestic and municipal uses receiving top priority followed by agricultural and stock-raising, electric power, other industrial uses, navigation, fishing and hunting, and any other beneficial uses.

The waters of the Rio Grande between Fort Quitman, Texas, and the Gulf of Mexico are allocated to the two countries as follows:

Mexico is to receive all of the waters reaching the main channel of the Rio Grande from the San Juan and Alamo Rivers, including the return flow from the lands irrigated from the latter two rivers; One-half of the flow in the main channel of the Rio Grande below the lowest major international storage dam; Two-thirds of the flow reaching the main channel of the Rio Grande from the Conchos, San Diego, San Rodrigo, Escondido, and Salada Rivers and the Las Vacas Arroyo; One-half of all other flows not otherwise allotted by this Article occurring in the main channel of the Rio Grande including the contributions from all the unmeasured tributaries not named in the Article, between Fort Quitman and the lowest major international storage dam.

United States is to receive all of the waters reaching the main channel of the Rio Grande from the Pecos and Devils Rivers, Goodenough Spring and Alamito, Terlinqua, San Felipe and Pinto Creeks; One-half of the flow in the main channel of the Rio Grande below the lowest major international storage dam; One-third of the flow reaching the main channel of the Rio Grande from the Conchos, San Diego, San Rodrigo, Escondido and Salado Rivers and the Las Vecas Arroyo, provided that this third shall not be less than 350,000 acre-feet (43,155 ha-m) annually; One-half of all other flows not otherwise allotted by this Article occurring in the main channel of the Rio Grande, including contributions from all unmeasured tributaries between Fort Quitman and the lowest major international storage dam.

Federal Law

The Federal Water Pollution Control Act (P.L. 92-500) sets forth its objectives in Section 101. Its objectives are to restore and maintain the chemical, physical and biological integrity of the nation's waters (Sec. 101 (a)). "It is the national goal that the discharge of pollutants into the navigable waters be eliminated by 1885" (Sec. 101(a) 1).

The administrator of the EPA must, in cooperation with other federal agencies, state water pollution control agencies and interstate agencies, prepare comprehensive programs for the prevention, reduction, or elimination of pollution of the navigable waters and ground waters, and improve the sanitary condition of surface and underground waters.

With some specific exceptions (302, 306, 307, 318, 401, 404), the discharge of any pollutant by any person is unlawful (Sec. 301(a)). Section 301(b) 1A commands that "efficient limitations for point sources, other than publicly owned treatment works, which shall require the application of the best practicable control technology currently available, be achieved not later than July 1, 1977." 2A of Section 301(b) commands that effluent limitations for categories and losses of point sources, other than publicly owned treatment works which shall require application of the best available technology for such category or class, which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, be achieved by July 1, 1983.

Section 402(a) 1 states that the administrator may issue a permit for the discharge of any pollutant, or combination of pollutants. The discharge must meet the effluent standards established by the Act. Discharge of pollutants means any addition of any pollutant to navigable waters from any point source. Therefore, all nonpoint sources are excluded from the effluent limitations subject only to analysis and study under Section 304(e). Point source refers to any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel, or other floating craft, from which pollutants are or may be discharged (Sec. 502(14)).

In NRDC vs Train (7 ERC 1881), the court held the administrator could not exempt point sources discharging pollutants from NPDES regulations. An exempted source included discharge from irrigation return flows from point sources where the flow is from less than 3,000 acres (1,215 ha). Thus, the EPA must include all irrigation return flows or reclassify irrigation as a nonpoint source of discharge.

SECTION 5

NATURE OF THE PROBLEM

WATER QUALITY STANDARDS

Although the river reach from Elephant Butte Dam to Fort Quitman is classified as being part of Texas in regard to the quantity of water delivered under the terms of the Rio Grande Compact, water quality standards have remained within the realm of the respective states of New Mexico and Texas. However, as the river has a significant flow only when water is being released from Elephant Butte Reservoir in New Mexico, water quality criteria have been established via agreement between the states. The criteria are related to discharge in the river and are in effect only when a certain minimum flow is exceeded.

Water quality standards for New Mexico were published in August 1973 with the purpose "to designate the uses for which the surface waters of the State of New Mexico shall be protected and to describe the water quality standards necessary to sustain the designated uses." The standards contain a specific Antidegradation Policy which states:

> Degradation of waters the quality of which is better than the stream standards established by the New Mexico Water Quality Commission is not reasonable degradation and is subject to abatement under the authority granted the Commission by the New Mexico Water Quality Act, as amended, unless it is justifiable as a result of necessary economic and social development. To protect the existing quality of water, the Commission under that Act will require the highest and best degree of effluent treatment practicable ("New Mexico Water Quality Standards," New Mexico Water Quality Commission, Aug. 1973).

General standards were formulated for all surface waters and specific standards for the Rio Grande Basin. Those standards relevant to irrigation return flows are contained in the specific standards.

Texas water quality criteria have been devised in accordance with the statement of policy of the Texas Water Pollution Control Act:

> It is declared to be the policy of the State of Texas to maintain purity of the waters of the State consistent with the public health and public enjoyment thereof, the propagation and protection of fish and wildlife including birds, mammals, and other terrestrial and aquatic life, the operation

of existing industries, and the industrial development of the State, and to that end to require the use of all reasonable methods to prevent and control the pollution of the waters of this State (Section 21.002).

In addition to a General Statement of Texas Water Quality Criteria, specific criteria have been established for reaches of the Rio Grande. The specific standards applied to the Rio Grande by both New Mexico and Texas are summarized in Table 8.

EXISTING WATER QUALITY

As early as 1918, the Bureau of Reclamation began collecting water samples from the river and some of the drains within the project area. These samples were analyzed for total dissolved solids (TDS or salinity). The drain sampling program has been expanded until at present it includes all of the major drains. River water quality records are now kept on a regular basis at San Marcial by the U.S. Geological Survey (USGS), below Caballo Dam by the USGS and at El Paso and Fort Quitman by the International Boundary and Water Commission (IBWC). The research report on "Discharge and Salt Burden of the Rio Grande Above Fort Quitman, Texas, and Salt-Balance Conditions on the Rio Grande Project" (Wilcox, 1968), by the U.S. Salinity Laboratory provided quality records for below Elephant Butte Dam, at Leasburg Dam and at the El Paso-Hudspeth County Line, in addition to the other stations, for the period 1934-1963. Intermittent records for some of these stations have been continued by the USBR.

The annual average values for total dissolved solids, weighted on a discharge basis, are shown for stations in the study area in Table 9. The averages, for the periods for which records are available, show that the concentrations of total dissolved solids in the river increase from 500 mg/l below Caballo Dam to 800 mg/l at El Paso and 1850 mg/l at Fort Quitman. Peak values of 1100, 3850 and 10,750 mg/l have been recorded at these stations, respectively. The established quality criteria are seldom exceeded.

Concentrations of total dissolved solids in the major drains of the Rio Grande project are shown in Table 10. The water quality in the drains may be compared to the water quality in the river at the point of diversion to the respective valleys, as presented in Table 9, and discussed earlier in this section.

Over the period for which common records are available, the concentration of total dissolved solids in the Rincon Valley increased from 500 to 1,020 mg/l on average, in the Mesilla Valley from 550 to 1,290 mg/l, in the El Paso Valley from 800 to 2,700 mg/l, and in the Hudspeth District from 1,500 to a figure in excess of 1,850 mg/l (this figure being the concentration of salts in the Rio Grande at Fort Quitman).

The sampling station at El Paso has the longest continuous record of TDS concentrations typical of valley conditions. Records have been kept since 1918, when two samples were taken during the year. The discharge weighted

TABLE 8. WATER QUALITY STANDARDS, MIDDLE RIO GRANDE VALLEY, TEXAS AND NEW MEXICO

	Texas Standards	New Mexico Standards			
	Presidio to New Mexico line	New Mexico line to 1 mile below Percha Dam	One mile below Percha Dam to headwaters Caballo Reservoir	Headwaters Caballo Reservoir to Elephant B. Dam	Elephant Butte Reservoir
Designated uses	Desirable uses: noncontact recreation; propagation of fish & wildlife; domestic raw water supply.	Irrigation; limited warm water fishery; livestock & wildlife watering; secondary contact recreation.	Irrigation; livestock & wildlife watering; marginal cold water fishery; secondary contact recreation; warm water fishery.	Fish culture; irrigation; livestock & wildlife watering; marginal cold water fishery; secondary contact recreation; warm water fishery.	Irrigation storage; livestock & wildlife watering; primary contact recreation; warm water fishery.
Applicability of standards	Flow ≥ 3500 cfs	Flow >350 cfs	Flow >350 cfs Storage ≥ 25,000 AF	Flow > 100 cfs	Storage ≥ 100,000 AF
Standards Parameter: Dissolved oxygen, mg/l	≥ 5.0	> 5.0	> 5.0 (≥ 4.0 for periods of 6 hrs. or less)	> 5.0	> 5.0 (24.0 for periods of 6 hrs. or less)
pH	7.0 - 9.0	6.6 - 8.8	6.0 - 9.0	6.6 - 8.8	6.6 - 9.0
Temperature, °C	35 (95 F)	≤ 34	≤ 32.2	≤ 25	≤ 32.2
Turbidity, FTU			50		50
Monthly logarithmic mean of fecal coliform bacteria, colonies/100 ml	≤ 1,000	< 1000, with no more than 10% > 2,000	< 100, with no more than 10% > 200	< 1000, with no more than 10% > 2000	< 100, with no more than 10% > 200
Total dissolved solids, mg/l	Average ≤ 1800	< 2000			
Sulphate, mg/l	Average ≤ 700	< 500			
Chlorides, mg/l	Average ≤ 500	< 400			

TABLE 9. TOTAL DISSOLVED SOLIDS AT SELECTED STATIONS.

Date	San Marcial	Caballo	Leasburg	El Paso	County Line	Fort Quitman
	Discharge weighted average TDS, mg/l					
1918				609*		
1919				680		
1920	441		552*	552		
1921	357		420	581		
1922	272		620	722*		
1923	--		420*	--		
1924	242		566	655		
1925	736		522	750		
1926	514		698	890		
1927	730		500*	1,287		2,491
1928	592		500*	765		2,088
1929	563		492	721		1,836
1930	593		714	1,022		1,972
1931	1,021		621	897		2,045
1932	470		608	883		1,985
1933	899		557	846		2,000
1934	809		669	926	e1,721	2,240
1935	611		713	912	e1,662	1,560
1936	544		633	868	e1,662	2,090
1937	427		574	831	e1,662	2,120
1938	500		537	801	1,486	1,760
1939	618		560	846	1,817	2,140
1940	736	603	640	919	1,868	2,260
1941	419	603	640	890	1,751	1,680
1942	360	419	441	581	831	882
1943	603	412	463	750	1,486	1,700
1944	397	463	522	787	1,589	1,770
1945	375	478	508	801	1,692	2,070
1946	522	471	515	816	1,949	2,320
1947	590	544	588	824	1,993	2,590
1948	338	559	596	838	1,905	3,040
1949	353	441	485	750	1,758	2,630
1950	449	456	500	772	1,795	2,740
1951	618	706	662	904	2,368	2,730
1952	360	434	522	735	2,251	3,860
1953	611	493	522	743	2,199	2,420
1954	883	758	824	956	1,964	1,270
1955	853	927	949	1,010	919	559
1956	677	853	875	1,050	--	375
1957	515	508	537	596	427	294
1958	383	537	559	721	772	801
1959	662	449	515	831	1,751	1,380
1960	427	515	581	860	2,207	2,090

(con't)

TABLE 9 (continued)

Year	San Marcial	Caballo	Leasburg	El Paso	County Line	Fort Quitman
1961	441	485	588	868	2,530	4,110
1962	368	427	485	801	1,971	2,690
1963	478	441	515	875	2,515	3,990
1964	567			1,060		4,440
1965	380			566		375
1966	418			691		1,100
1967	652	503		816		2,240
1968	447			890		2,900
1969	415			780		3,074
1970	412	505		824		2,631
1971	427	475		821		4,844
1972	576			908		2,843
1973				833		2,438
Years of Record	52	27	44	55	12	46
Discharge Wt. Averages	482	504	558	802	1,498	1,851

* = 5 samples or less e = partly estimated.

average concentration for each year over the period of record has been plotted in Figure 3, showing the variations of water quality with time. Through to the early 1920's, concentrations at El Paso were comparatively low, probably corresponding to the lack of drainage facilities. As irrigation water was applied, the deep percolation contributed to a rise in the water table rather than rapidly returning to the river through drains. With the completion of the drainage system in 1925, the water table would have been lowered and the accumulated salts returned to the river. Later, the salt concentration in the river declined to a lower level (averaging about 800 mg/l), which it has maintained fairly consistently ever since.

SOURCES OF WATER QUALITY DEGRADATION

During the course of the cycle of diversion of water to farmlands, percolation through the soil profile and return of unconsumed water to its river source, a number of changes are likely to occur. Two of these changes, related to the quality of water downstream of an irrigated area, are the concentrating effect and salt pickup.

TABLE 10. DISCHARGE AND SALT CONCENTRATIONS OF DRAINAGE WATERS OF THE RIO GRANDE PROJECT

Year	Rincon Valley			Mesilla Valley			El Paso Valley		
	Flow		TDS	Flow		TDS	Flow		TDS
	AF	ha-m	mg/l	AF	ha-m	mg/l	AF	ha-m	mg/l
1926	33,335	4,110	800	185,174	22,831	1,560	95,330	11,754	3,730
1927	31,442	3,877	920	192,446	23,729	1,530	97,406	12,010	2,840
1928	34,537	4,358	790	195,389	24,091	1,230	111,437	13,740	3,370
1929	35,120	4,330	940	191,157	23,570	1,350	118,586	14,622	3,300
1930	31,935	3,938	900	183,774	22,659	1,660	132,471	16,334	2,640
1931	36,719	4,527	1,000	196,546	24,234	1,590	131,200	16,177	2,710
1932	39,294	4,845	870	194,358	23,964	1,370	138,069	17,024	2,680
1933	41,024	5,058	1,010	105,364	12,991	1,310	137,181	16,194	2,490
1934	40,871	5,039	1,010	217,785	26,853	1,250	132,816	16,376	2,610
1935	26,900	3,317	1,000	167,100	20,603	1,240	109,500	13,501	2,830
1936	28,600	3,526	980	185,200	22,835	1,210	112,900	13,921	2,790
1937	30,200	3,724	1,010	180,400	22,243	1,360	125,100	15,425	2,640
1938	31,340	3,864	1,130	185,870	22,918	1,280	130,210	16,055	2,660
1939	39,630	4,886	1,010	217,390	26,804	1,110	129,680	15,990	2,690
1940	33,590	4,142	1,040	225,460	27,799	1,210	122,550	15,110	2,620
1941	33,970	4,189	1,140	215,560	26,579	1,210	127,310	15,697	2,540
1942	43,846	5,406	1,040	235,922	29,089	1,210	148,746	18,340	2,420
1943	43,590	5,375	1,000	256,910	31,677	1,120	139,590	17,211	2,240
1944	36,667	4,521	1,010	262,369	32,350	1,210	148,653	18,329	2,340
1945	34,820	4,293	900	225,100	27,755	1,120	154,650	19,068	2,250
1946	--	--	--	--	--	--	--	--	--
1947	--	--	--	--	--	--	--	--	--
1948	--	--	--	--	--	--	--	--	--
1949	33,780	4,165	--	--	--	--	--	--	--
1950	33,103	4,082	980	222,322	27,412	1,150	150,588	18,568	2,290
1951	16,530	2,038	960	126,750	15,628	1,370	77,480	9,553	2,790
1952	16,040	1,978	1,030	82,300	10,147	1,180	73,220	9,028	2,650

If only enough water is added in a given irrigation to bring the soil to field capacity, there may be little or no movement of water below the root zone. The salts and other impurities applied with the water remain in the soil, to be concentrated in the constantly decreasing amount of soil water as a result of evapotranspiration, or for some salts to be precipitated in the soil. Continued irrigations of this type, coupled with the constant removal of relatively pure water by plants in the evapotranspiration process, induces a salt buildup in the soil, increasing the concentration of the soil water and ultimately presenting the possibility of inhibiting plant growth. Therefore, some water must move through the soil profile, otherwise a salt balance in the soil profile cannot be maintained. This water may contain essentially all of the salts applied in the irrigation water, but in a quantity of drainage water less than the applied water by the amount of water consumed by the crop. This is the concentrating effect of irrigation.

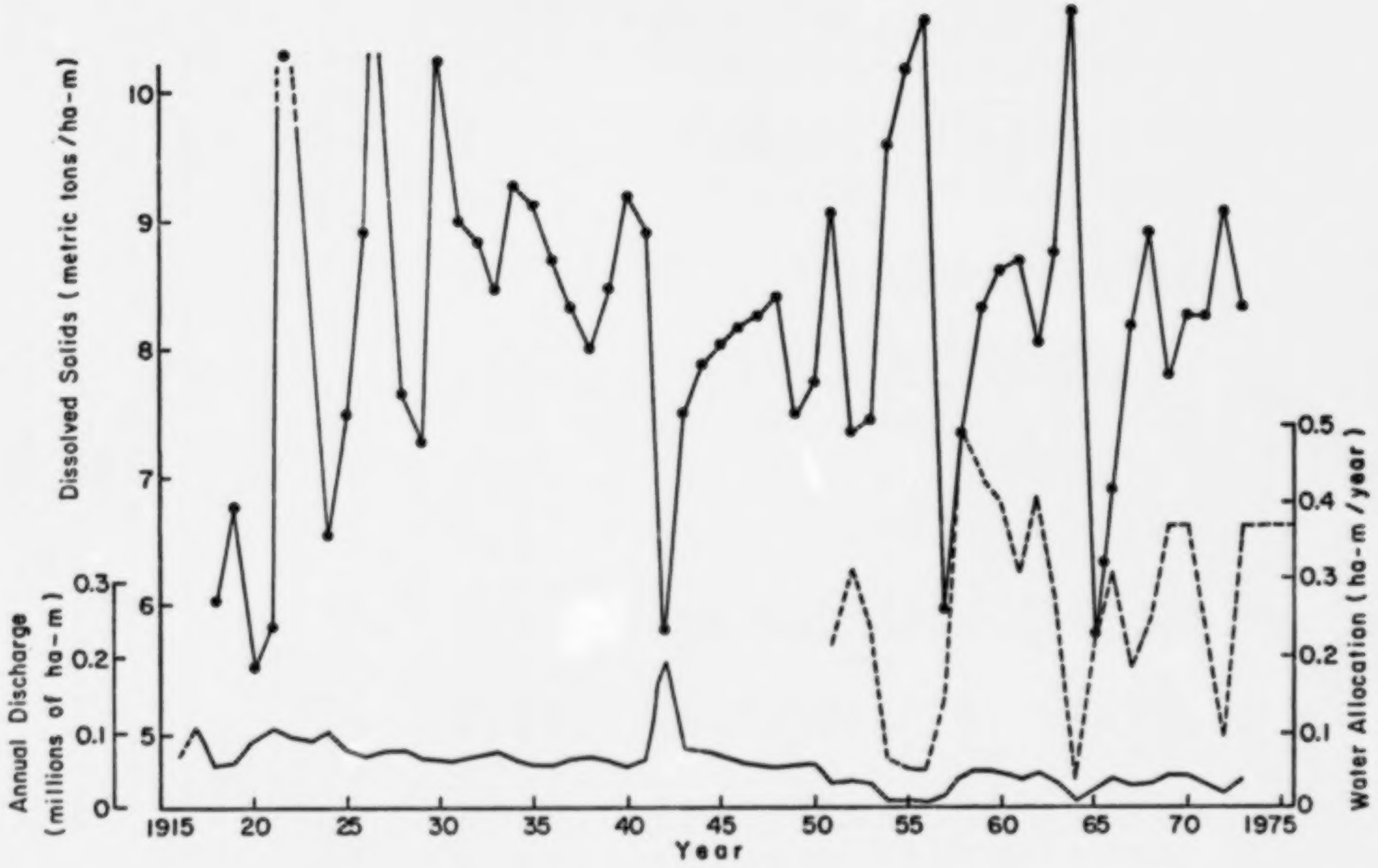


Figure 3. Variations in water quality at El Paso.

In the process of percolating through the soil profile, irrigation water may dissolve soluble mineral constituents inherent in the soil which are then returned to the river in the drainage water. The increase in the quantity of salts leaving a given area compared to the quantity introduced by the irrigation source is referred to as the salt pickup. The total salts carried by a stream per unit of time is referred to as the salt load, in contrast to the salt concentration, which is the quantity per unit of volume.

The concentrating effect is an unavoidable consequence of consumptive use of irrigation water by crops. It is independent of the amount of water applied assuming crop needs are met. The salt pickup effect, however, is avoidable, i.e., it may be reduced. The amount of constituents carried from the soil, in addition to the amount applied in the irrigation water, will depend on the quantity and quality of the applied water and on the availability of soluble constituents in the soil profile. In this case, the quantity of water applied may make a vast difference to overall water quality. As the dissolved products are transported by leaching, further dissolution is able to take place. Hence, the salt pickup effect may be greatly reduced by reducing the amount of water passing through the soil profile, viz. deep percolation from croplands and seepage from canals and laterals.

Numerous studies have shown that the concentration of salts in the Rio Grande increases as it passes through the study area. This was shown in Table 9, wherein total dissolved solids at selected stations were noted. Therefore, a study has been made of the salt loads to see if the potential exists to reduce the quantity of salts returning to the river from irrigated areas.

The quantity of total dissolved solids (salinity) entering and leaving each valley section of the study area has been computed for the time period for which records are available. The difference, the salt loading for that section, is plotted on Figures 4 and 5. The salt inflow and outflow that does not pass the respective gauging stations (ground water flow) has been assumed to be relatively small in comparison with surface flows. Meyer and Gordon estimate ground water outflow for the Mesilla Valley to be 160 acre-feet (20 ha-m) per year in 1970 and 1971 (compared to a surface water outflow of 360,700 and 244,160 acre-feet (44,474 and 30,105 ha-m), respectively. For the El Paso Valley (to the Hudspeth County line), they estimated ground water outflow to be 2,100 acre-feet (259 ha-m) per year for each year of the period 1969-1971, while surface water outflows for the same period ranged from 53,980 (6,656 ha-m) to 144,550 (17,823 ha-m) acre-feet per year. Because of similarities in topography, the quantity of ground water outflow from the Rincon Valley would be expected to be similar to the quantity from the Mesilla Valley, while the quantity from the Hudspeth County Irrigation District would be expected to be similar to the quantity from the El Paso Irrigation District.

Inspection of Figure 4 reveals that a favorable salt balance has generally been maintained in the Rincon Valley (i.e., more salt leaves the valley than is introduced to it). For the period 1934-1963, an average of one ton of salt per irrigated acre per year was added to the load in the river. In the Mesilla Valley, however, Figure 5 shows that less salt has left the valley

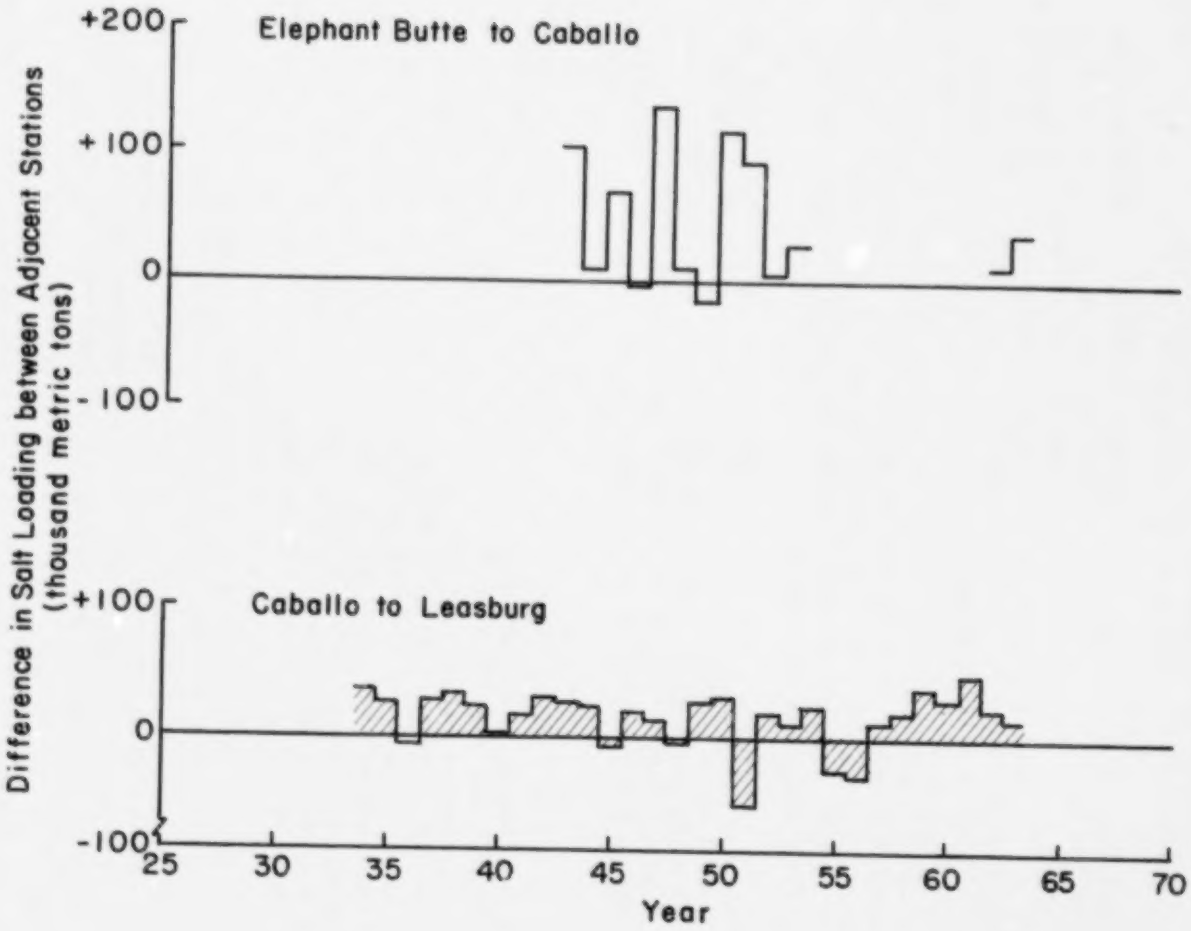


Figure 4. Salt loading in Rio Grande between Elephant Butte Reservoir and Rincon Valley.

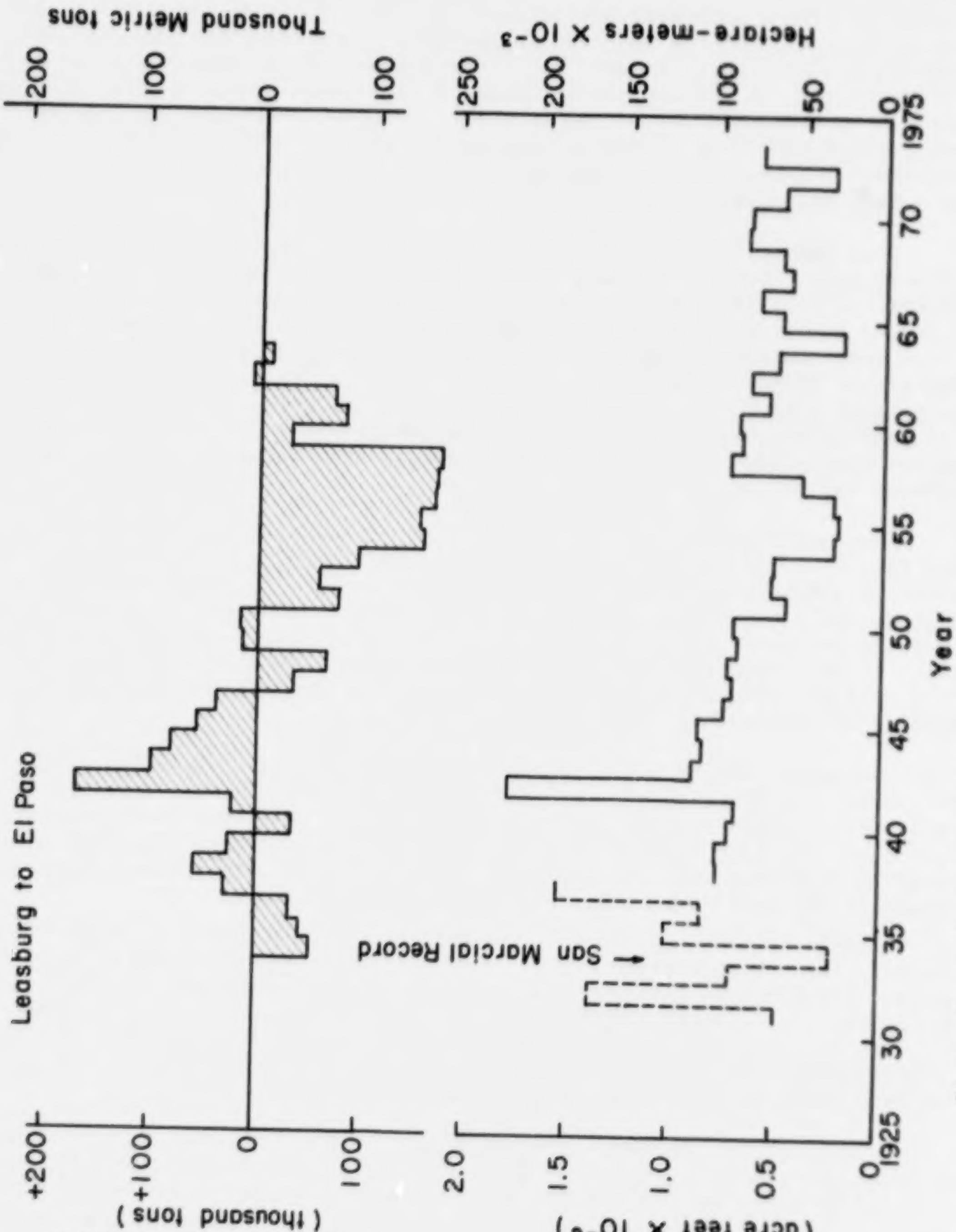


Figure 5. Salt loading in Rio Grande from Mesilla Valley.

than has been introduced. In the El Paso Valley, the cumulative sum over the period of record approximately balances (Figure 6). In the Hudspeth District, the salt balance has been unfavorable in nearly every year for which records are available (Figure 7). For the period 1934-1963, a total of 2,808,000 tons (3,088,800 metric tons) of salt remained in the district, which would be an accumulation of 156 tons per irrigated acre over that period, if the full 18,000 acres (7,290 ha) had been irrigated. However, as the irrigated area averaged only about 13,000 acres (5,265 ha) over that period, some areas must have accumulated even more salt per acre.

Over the period 1927 to 1972, 23 million tons (25.3 million metric tons) of salt have entered the study area at San Marcial as surface inflow, and 15 million tons (16.5 million metric tons) have left at Fort Quitman. The balance, 8 million tons (8.8 million metric tons) has been removed from the river and retained in the soil of the project lands or in the ground water. Therefore, although the concentration of salts in the river water increases on passing through the study area as the inevitable consequence of irrigation, the loading has decreased. Overall, the downstream water quality has been better than would be expected of an irrigated area in which a favorable salt balance was maintained.

Consideration has therefore been given to the river section upstream of San Marcial in an endeavor to identify possible sources of degradation. If water of a higher quality could be delivered to the Rio Grande Project, the project lands would have a lower leaching requirement and a lower quantity of salts may be washed into the river. Extensive studies of salinity conditions in the upper Rio Grande could not be found, although the records of the USGS allowed a cursory examination to be made of some causes of the water quality deterioration.

The waters of the upper reaches of the Rio Grande in Colorado (above Del Norte) are of particularly high quality, generally having less than 100 mg/l TDS, although nitrate levels are generally quite high. Near Lobatos, just above the New Mexico state line, the TDS concentration increases to a range of from less than 200 to more than 500 mg/l, with a corresponding increase in the salt load being carried by the river.

Between Lobatos and Otowi Bridge (immediately northwest of Santa Fe), the salt load being carried by the river increases by an average of approximately 150,000 tons (165,000 metric tons) per year, as shown in Figure 7, due to the increased discharge. The principal tributary is the Rio Ghama. However, the average annual TDS concentration ranges from less than 200 to less than 300 mg/l, with occasional values over 500 mg/l. The concentration has thus remained approximately the same as at Lobatos.

At San Marcial, however, the concentration has increased to a discharge weighted average annual value of 300 to 900 mg/l, as shown in Table 9, with occasional values as high as 1800 mg/l (which correspond to low flows in the river). This indicates that the salt load being carried by the river has increased more than the discharge. For the period 1934 to 1972, the salt load at San Marcial was an average 168 thousand tons (185 thousand metric tons) per year more than at Otowi Bridge. During only two years in that period was the load less.

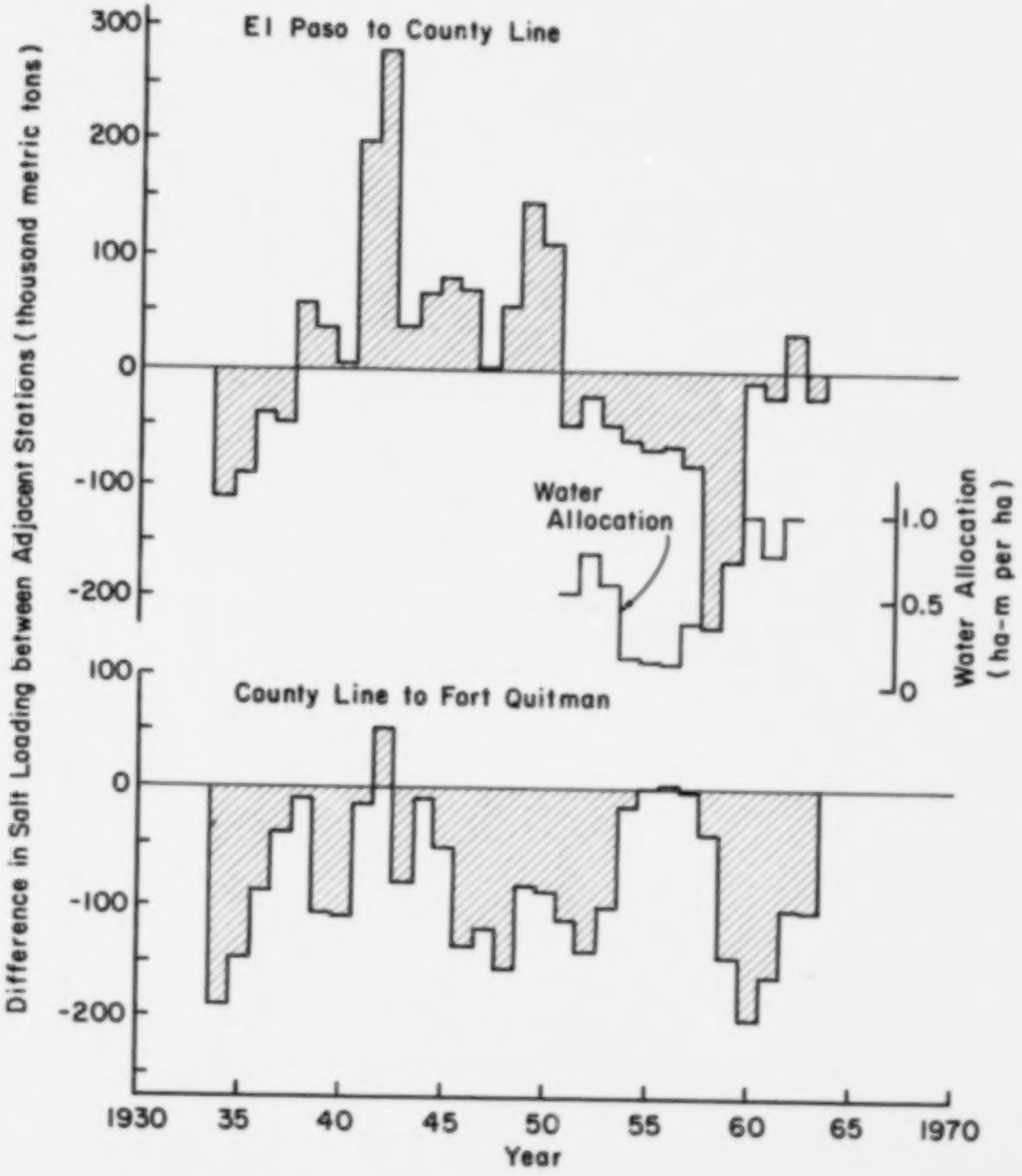


Figure 6. Salt loading in the Rio Grande from El Paso Valley.

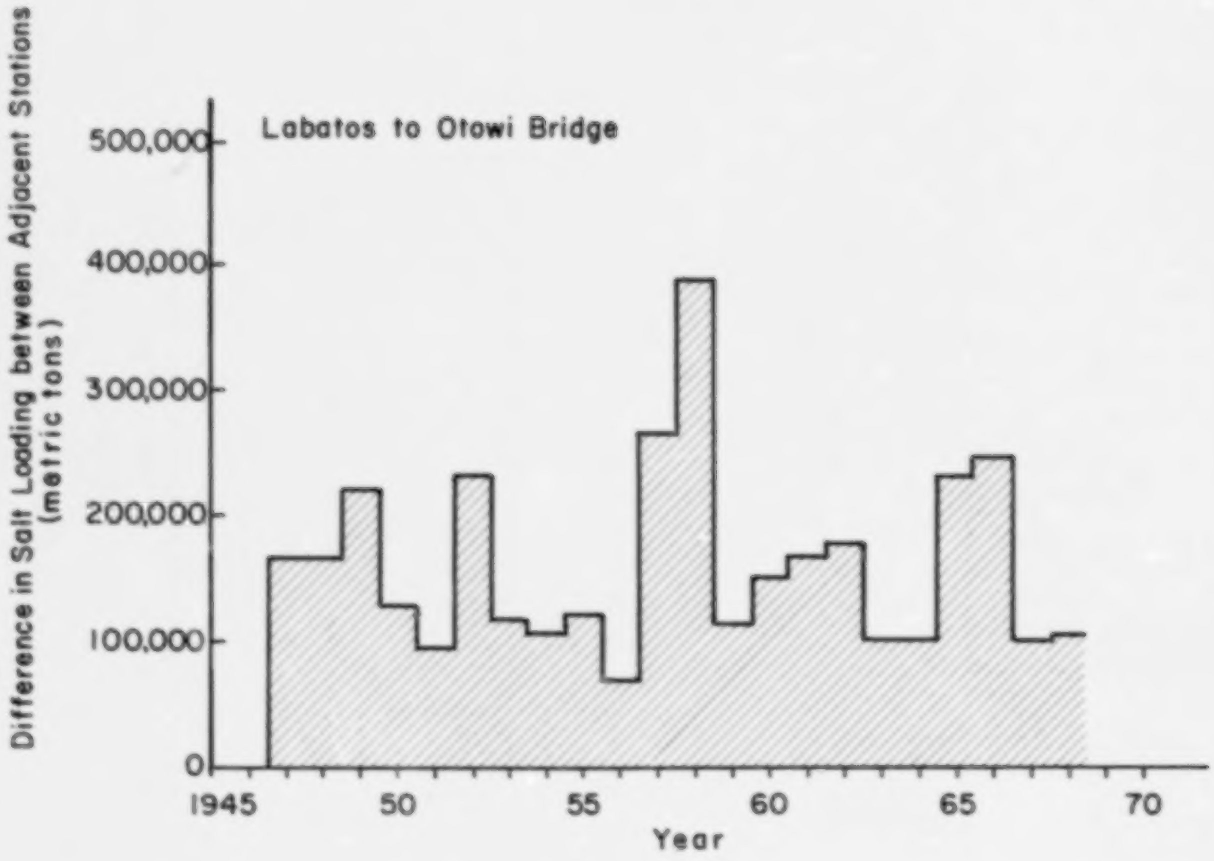


Figure 7. Salt loading in the Upper Rio Grande.

An obvious source of this loading would be the Middle Rio Grande Project. To estimate the load contributed by this project, contributions from all other sources must first be deducted. Quality records are available for a number of years for Galisteo Creek, Jemez River, Rio Puerco and Rio Salado, which are the major tributaries to this section of the river. The annual salt contribuation of these four streams has been plotted on Figure 8 for those years for which records are available, and compared with the increased loading between Otowi Bridge and San Marcial. The graph shows that in many of the years of record the total increase in salt load between these two stations can be attributed entirely to these four tributaries. The contribution from ungauged tributaries has not been estimated. In those years where these tributaries contribute a greater amount of salt than the increased salt load in the river between the two stations (Otowi Bridge and San Marcial), the irrigated lands of the Middle Rio Grande Project must, in fact, be removing salt from the river (storing salts in the soil profile or ground water).

The greatest contributor of salt is the Rio Puerco, which contributes on average (1966 to 1974) 71,000 tons (78,100 metric tons) per year. The concentration ranges up to 9,060 mg/l, with a discharge weighted average annual concentration of between 1,280 and 1,860 mg/l. Although an ephemeral stream, the Rio Puerco supports about 11,000 acres (12,100 metric tons) of irrigated agriculture. Records are inadequate to calculate the contribution of this irrigated area to the salt load carried by the stream. However, the records do show that high flows are generally of high salt concentration, whereas low flows are of relatively low salt concentration. The high flows would be associated with natural runoff rather than irrigation return flows; hence, it is reasonable to surmise that the salt pickup is largely from natural sources. This would also be true of Galisteo Creek and the Rio Salado, both of which support very little irrigated agriculture. The quality of the water contributed by the Jemez River is quite good.

We can safely conclude from the evidence in the records that the load of salt added to the Rio Grande above San Marcial is due to natural causes and not from irrigated agriculture.

A study of inflow-outflow relations during years of full water supply allows an assessment of overall salt-balance conditions in a given river sector and shows whether salt pickup is occurring. In years of short supply, when large quantities of ground water are pumped, it becomes more difficult to determine whether salt contributions come from pickup or result from the higher salinity concentration of ground water supplies.

Serious water shortages on the Rio Grande Project were first experienced in 1951. Although, in previous years, the carryover storage in Elephant Butte Reservoir had sometimes reached seriously low levels, a seasonal allocation of at least two (0.61 ha-m/ha) and generally 3 acre-feet per acre (.9 ha-m/ha) had always been possible. In 1951, an allocation of only 1.75 acre-feet per acre (0.53 ha-m/ha) was made and a full allocation was not available again until 1958. In 1956, the allocation dropped to 4.7 acre inches per acre (0.12 ha-m/ha).

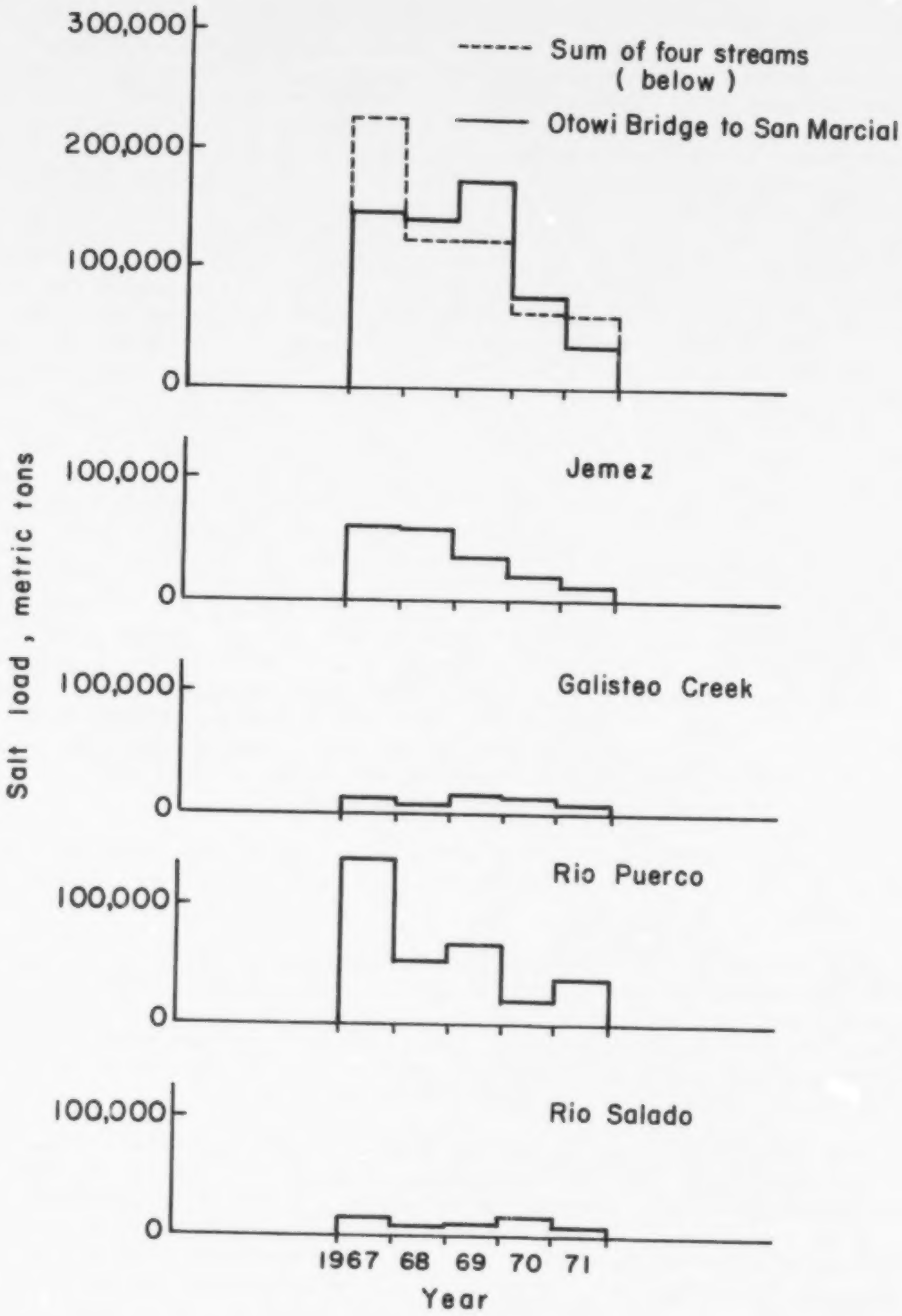


Figure 8. Contribution of inflowing streams to increased salt load from Otowi Bridge to San Marcial.

Consequently, extensive well drilling was carried out in the early 1950's with approximately 1,800 wells drilled in the Elephant Butte Project area. These wells were mainly drilled into the river alluvium to depths ranging from about 15 to 200 feet (5 to 61 m).

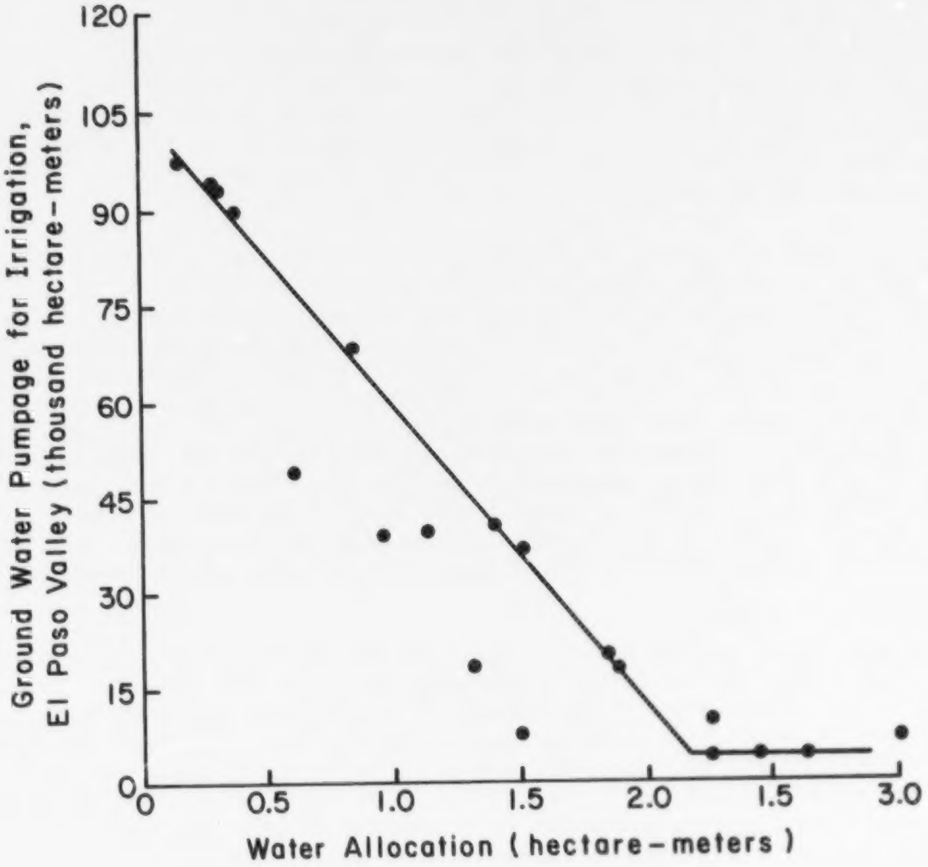
The TDS of water extracted from these wells ranged generally from around 1,100 mg/l in the upper Rincon Valley to 1,400 mg/l in the mid-Mesilla Valley, 2,500 mg/l in the middle of the El Paso District, and 5,000 mg/l in the lower part of the Hudspeth District. However, wide variations occur within a given area as the quality is subject to a number of environmental factors such as the distance from canals or drains (Basler and Alary, 1968).

The quantity of ground water pumped in a season is inversely proportional to the amount of surface water allocation as shown in Figure 9. In those years of low project water allocation, the amount of ground water pumped rose rapidly. However, this was not sufficient to bring the total water supply up to full allocation of 3 acre-feet per acre (.9 ha-m/ha) (based on data from the El Paso Valley only, for which ground water pumping records are available). Drain flows in those years were below normal, probably due to a combination of a lower water table because of ground water pumping and less deep percolation because of the lower water application per hectare. With ground water generally having salinity of two to three times that of adjacent surface waters, and in some years making up the major portion of the total water supplies, a rapid buildup in soil salinity would therefore be expected in water-short years.

The quality of ground water in each valley was shown by Wilcox to have a similar TDS concentration to the drainage water from that valley. Should an extended water shortage occur in the valley and extensive ground water pumping be necessary to provide an adequate water supply, the salts from the drainage water would in effect be recycled back onto the land together with salts from the ground water. Later, additional amounts of water would need to be applied to crops to maintain a satisfactory salt balance in the root zone. Very little of the additional deep percolation would find its way to the drains, as the pumping would have lowered the water table to a level below the drains.

The restoration of a full surface water supply after a number of years of heavy ground water pumping would be expected to be followed by a heavy salt loading of the drains as accumulated salts would be leached from the soil profile. Wilcox found this to be evident from the data for the Rincon Valley, and it is also evident from the data plotted for the El Paso District shown in Figure 10. (The El Paso District has been used, rather than Rincon Valley or Mesilla Valley, because it has the most comprehensive data on ground water withdrawal.)

In summary, in years of full water allocation, a favorable salt balance is generally maintained in the Rio Grande Project (i.e., the river is being loaded with salt). In water-short years, lower quality ground water is being pumped to make up the shortfall. The salts brought up in the ground water are accumulated in the soil until such time that sufficient surface water is available for leaching with the leachate eventually returning to the river.



SOURCE: Texas Water Development Board.

Figure 9. Effect of water allocation on ground water use.

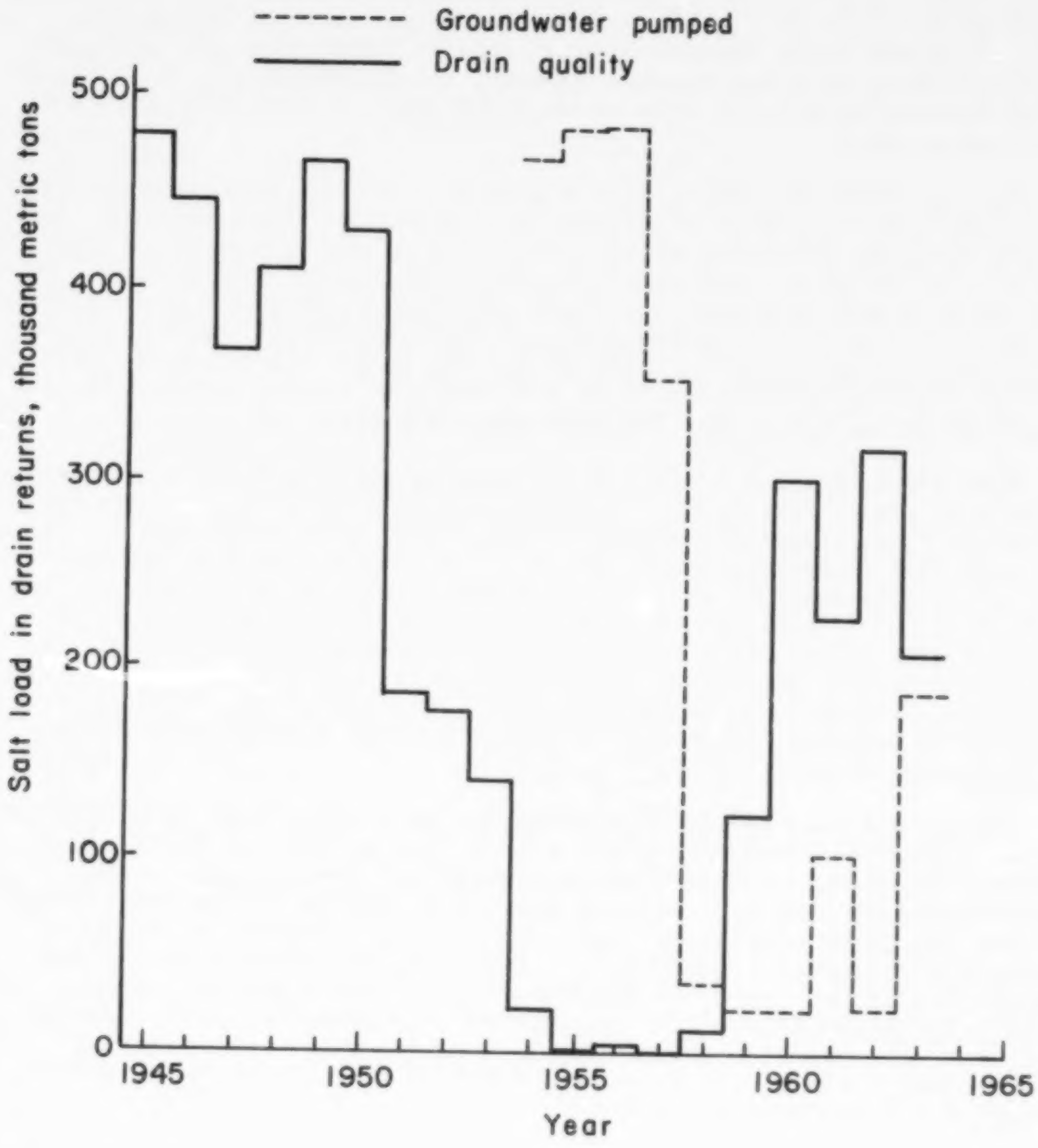


Figure 10. Relationship of ground water pumped to load of salt in drains.

PROBLEMS DUE TO EXISTING WATER QUALITY

Based on available reported information, there appear to be no serious problems resulting from the use of existing irrigation water supplies in the Rincon Valley. The only salt affected soils appear to be at the extreme lower end of the valley where the water table is forced near the surface by the constriction of Selden Canyon. However, as mentioned previously, Rincon Valley does add to the salt load in the Rio Grande, thereby affecting downstream water users.

Mesilla Valley encounters only limited problems resulting from the water quality of existing surface irrigation water supplies. There are some fields which have become salinized, mostly as a result of high ground water levels; however, the use of more saline ground water supplies for irrigation may have contributed to this problem. The use of the more saline ground water supplies for irrigation presents problems during extended periods of drought, as the soil salinity undoubtedly increases in the root zone. The increased soil salinity undoubtedly would result in decreased crop yields, although this cannot be conclusively proved from published crop yield data.

Most of the problems of quality of existing water supplies are confronted by users in the El Paso Valley. The effects of poor water quality are most pronounced in the lower portions of El Paso Valley in Hudspeth County. There, the water supply consists mostly of irrigation return flows from the upper El Paso Valley. Agriculture is largely limited to salt tolerant crops, and the value of output is considerably restricted by this limitation. The problem is illustrated by the decline in the irrigated area devoted to cotton. In 1950, 84 percent of the irrigated area was planted to cotton; in 1974, only 38 percent was used for this important crop. Correspondingly, the area of pasture has increased from virtually nothing in 1950 to 26 percent of the irrigated area in 1974.

The agricultural productivity of Rio Grande Project lands in El Paso Valley is also hindered by the quality of irrigation water supplies. The combination of more saline surface water supplies during drought periods, and having to use even more saline ground water supplies during these drought periods, has contributed to soil salinization. The interactive effects of surface and ground water supplies upon soil salinity cannot be established at this time because there are no field data to support such an analysis. However, the impact of salinity upon agricultural productivity is visually evident at many places in this area. Again, it is difficult to utilize reported crop yield data to document the effects of salinity, but a general decline in cotton yields is evident.

A potential problem of use of the Rio Grande exists with the prospective need for river water for urban uses. Presently, the city of El Paso obtains its water from underground sources. Wells located north of the city and the river are utilized to produce potable water. But the rapid growth of the city may require use of water from the river. This might require a significant diversion of water from agriculture and it would certainly involve expensive treatment of the river water to remove salts and thus make it usable.

FUTURE WATER QUALITY CONSIDERATIONS

For 212 miles (341 km) below Fort Quitman, the Rio Grande practically ceases to flow, being supplied only by a minor amount of low quality return flow and intermittent discharge from tributary arroyos of higher quality. With the exception of 1942, when Elephant Butte Reservoir spilled for the only time in its history, no excess river discharge has passed Fort Quitman since 1915 when the reservoir began storing water. Over the period 1884-1914, the mean discharge passing Fort Quitman was 750,000 acre-feet (92,475 ha-m) per year (Schroeder, 1958). Over the period 1938-1973 the mean discharge was 76,000 acre-feet (9,371 ha-m) per year for those years not including 1942.

Although the quality of water below Fort Quitman may not be of major consequence, consideration must be given to the quality of water delivered to the irrigated areas between Elephant Butte Reservoir and Fort Quitman. Each year there is produced in the Rio Grande Project a volume of produce that is significant to the regional supply. The grain, hay and vegetable crops, plus the livestock supported by feed crops, have value which approaches $80 million annually. The agricultural enterprises support a growing and important supply industry, and the produce is a raw material source for many processing plants. This contribution of irrigated agriculture to the regional economy is placed in jeopardy by salt accumulation in soils. Water quality is a significant consideration in the maintenance of a viable agriculture in the region.

The primary cause of water quality deterioration as it moves through the study area has been shown to be the concentrating effect of irrigation. The most serious effects are related to the occurrence of water shortages. To maintain the water quality at suitable levels, these shortages would need to be prevented. Obviously, the further expansion of the irrigated area cannot be contemplated within the limits of the existing water resources. Indeed, it may be necessary to retire some presently irrigated lands from production to achieve levels of water quality suitable to a continuing, productive irrigated agriculture. This possibility must be recognized and considered for the future.

Prior to the early 1950's, a full water allocation (3 acre-feet/acre; .9 ha-m/ha) had always been possible on the Rio Grande Project. During the disastrous drought of the middle 1950's, a total of only 29.7 inches (754 ml) was delivered over the four-year period 1954-57. This was followed by another period of serious water shortages over the period 1963-68. Subsequent investigation (Jetton and Kirby, 1970) showed that the amount of water delivered to Texas by Colorado was less than the proportion of the catchment yield due under the terms of the Compact. The ensuing injunction by Texas assured that the full compact discharge will be maintained, which will go a long way towards ensuring that future shortages will not be as severe as those which occurred in the mid-1960's.

A major factor to be taken into consideration is the attitude of Mexico to the quality of water being diverted into the Acequia Madre. At present, this is an unknown element. Mexican farmers seem anxious to expand irrigation in the Juarez area, and they are not presently objecting to the quality of water they receive. They recognize that American farmers in the El Paso District use the same water, and they are aware that the quality of water in the river at El Paso has not changed significantly over the last 50 years. Yet, one should consider here the significance of the population increase in Juarez and the resulting increase in demand for water. This has also been a shortfall in the period 1951-1968. In 1964, the allocation was only 6,653 acre-feet (820 ha-m), compared to the Treaty quantity of 60,000 acre-feet (7,398 ha-m). The demand for additional water supplies is indicated by the extensive drilling for ground water for both urban and irrigation use in the Juarez Valley over the past few years. Therefore, although Mexico may feel bound by the Treaty to accept the quantity limitation, it could conceivably request additional water for leaching because of the poor quality, or additional water to dilute the existing supply. If additional water were delivered to Mexico, less would be available for agricultural uses on the United States side, which would require either a curtailment in cropped acreage or improved irrigation water management practices.

SECTION 6

CAUSES OF THE PROBLEM

INTRODUCTION

Though the water quality problem has thus far been presented in terms which make it seem to be a physical phenomenon, it is in fact a more complex problem of physical, biological, economic and legal relationships. Water is employed in agriculture because farmers have rights of use. The extent of water use is dictated by both physical and economic considerations. The degree of pollution is affected by costs of water as well as by volumes employed and methods of application. These relationships must be understood if the problem is to be successfully treated.

PHYSICAL CAUSES

The concentration of dissolved solids in the water stored in Elephant Butte Reservoir is higher than that in the headwaters of the Rio Grande due to naturally saline inflows from tributaries and to return flows from irrigation in Colorado and northern New Mexico. However, as discussed in earlier sections, the quality of the water released for use in the project is still sufficient for most uses, i.e., most crops which can be grown in the area. By the time the water leaves the project, it has suffered serious degradation.

The primary cause of this degradation is the concentration of salts in return flows, by the process described earlier in this report. As long as irrigated agriculture is maintained in the area, the quality of water in the river will deteriorate.

The water quality deterioration is exacerbated by the chronic water shortages that occur in the project area. These cause virtually all of the water released to the project to be diverted for irrigation, with little available for dilution of return flows to the river. In addition, during times of water shortage, lower quality water is pumped, contributing additional salts to the system.

Farm management practices are generally consistent with optimizing the returns at the individual level, to the detriment of downstream users. Heavy leaching is usually carried out early in the season, and often later in the season, being apparent from observation of water ponded on the fields and from the quantity of drain flows. Although a water shortage exists, it is highly likely that much water is wasted, particularly in the upper portions of the project area. The percolation of this water through the soil profile causes the water to be of a lower quality than if it had been left in the river.

ECONOMIC CAUSES

Inefficiency in Water Use

In most irrigated areas, available supplies of water are allocated among farmer-users on the basis of the rights they have established in the past. The allocation is thus established on legal rather than economic grounds. This being the case, the users tend to apply throughout the irrigation season all the water to which they are entitled. There are frequent overapplications of water to crops, water percolates into the subsoil beyond the root zone, and then moves laterally to receiving streams or downward into a shallow aquifer. As it moves, this return flow picks up salts which occur naturally in the soils and transports them to the stream or aquifer.

Application of excessive amounts of water are attributable to allocations which exceed need plus local water prices (conveyance costs) which are too low to encourage efficient use. This problem of price is one of ineffective reflection of the "opportunity cost" of water, i.e., its value in alternative uses. Most productive factors are allocated through markets. There is opportunity for competing users to bid for, not only the factors, but also the raw materials from which the factors are produced. So prices of the factors reflect their alternative uses and the market allocates resources and factors so that efficient use is realized.

In the study area there exists a market mechanism which permits transfers of all or portions of allocations within the boundaries of the districts and among agricultural users. It has as its basis the collective water right of district members and it functions via an informational system in the district through which needs and availability can be communicated. It does not reflect alternative, nonagricultural uses and so is imperfect. But it does allow the expression of demand for agricultural uses and so it allocates water to higher valued uses to the extent that it is used in the project area.

Significance of this constrained market is evident if one recalls the system for allocating and using the limited water supplies at the valley. Construction of Elephant Butte Dam and creation of the Rio Grande Project were accomplished in 1916. The Bureau of Reclamation appropriated the water rights in the project area (by Act of Congress) and facilitated the development of the irrigation districts in the Mesilla and El Paso Valleys. Each member was given an equal allotment of water for every acre he proposed to irrigate. Water rights were tied to the land, so that they could not be transferred out of the district or directed to nonagricultural uses.

The water allotments were freely transferable on a temporary basis within the irrigation district. A mechanism for debiting and crediting members' water accounts in the district office was devised to facilitate exchanges.

Negotiation of the price for any exchange was accomplished by the buyers and sellers.

Importance of exchanges within districts is evident when one recognizes that: 1) the planned, annual allotment, i.e., a "full" allotment, is only three acre-feet per acre; 2) actual allotments have been quite variable and as little as five inches per acre (0.13 ha-m/ha) (see Table 11); and 3) there are significant differences in values of crops produced in the project area. In water-short years, farmers with pecan orchards bid for and pay well for allotments of water available to neighbors. They must keep their trees alive and they wish to produce crops of valuable nuts. Similarly, producers of vegetable crops and cotton bid for allotments to produce high value crops. Transfers of allotments from low to high value crops result in a more efficient use of water. Conservative use is ensured by the small "full" allotments and by the relatively high costs of water as the allotments are moved into high valued uses. The limited market functions to provide for comparatively efficient use of this limited resource when it is well used.

Two problems exist with respect to an evaluation of the water market in the valley: 1) the exchange mechanism only functions to a significant extent in the Elephant Butte Irrigation District; and 2) soil-water relationships within the Project area are not so well established as to judge accurately the real impact of water transfers on quality of return flows.

Records of transfers within the Elephant Butte Irrigation District in the year 1975 show a total of 526 transfers taking place. The quantity of water transferred ranged from ½ acre-foot to 500 acre-feet (.06 to 62 ha-m), and averaged 13.3 acre-feet (1.64 ha-m) per transfer. During that same period, only ten transfers occurred within the El Paso County Water Improvement District No. 1. This confinement of the market to one district limits its effectiveness in reallocating water.

Current investigations at New Mexico State University are designed to determine soil-water relationships (irrigation efficiencies) and the associated qualities of return flows. The plots are irrigated at different levels of efficiency (80 percent efficient, 90 percent efficient, and 100 percent efficient). Return flow quality is measured and compared to the efficiencies at which the plots were irrigated. Investigations to this point find greater variations among plots than among efficiency treatments. This is explained by the extreme variability in the soil profile in the Rio Grande Project. So, the improved efficiency of water use which is logically attributable to the market reallocation is hard to prove. The differences in soils cause the efficiency improvements to be obscured.

Externalities

Further complicating the problem of agricultural pollution of river water is the very practical ability of farmers to avoid paying the costs associated with the increased salinity in the return flows. There is no mechanism to force them to pay, to internalize, this production cost. In his attempt to maximize profits, he therefore does not pay the costs of pollution. He selects production methods and techniques which will maximize net returns.

TABLE 11. IRRIGATION ALLOTMENTS AND RESERVOIR STORAGE

Year	Storage		Initial Allotment		Total Allotment for Year		Pumping
	AF	Ha-m	AF/acre	Ha-m/ha	AF/acre	Ha-m/ha	
1935	488,000	60,170	1.50	0.46	3.00	0.91	No
1947	488,900	60,281	1.75	0.53	1.75	0.53	No
1951	397,200	48,975	1.75	0.53	1.75	0.53	No
1952	108,600	13,390	0.21	0.06	0.21	0.06	Yes
1953	483,300	59,591	1.00	0.30	1.90	0.58	No
1954	185,200	22,835	0.42	0.13	0.50	0.15	Yes
1955	176,200	21,725	0.21	0.06	0.42	0.13	Yes
1956	233,900	28,840	0.33	0.10	0.39	0.12	Yes
1957	83,900	10,345	0.10	0.03	1.17	0.36	Yes
1958	834,400	102,882	1.75	0.53	4.00	1.22	No
1959	1,172,600	144,582	3.00	0.91	3.50	1.07	No
1960	699,700	86,273	2.25	0.69	3.25	0.99	No
1961	497,800	61,379	1.25	0.38	2.45	0.75	No
1962	468,200	57,729	1.75	0.53	3.25	0.99	No
1963	499,600	61,601	1.85	0.56	2.00	0.61	No
1964	200,400	24,709	0.25	0.08	0.33	0.10	Yes
1965	176,400	21,750	0.17	0.05	1.85	0.56	No
1966	613,240	75,612	1.75	0.53	2.50	0176	No
1967	440,800	54,351	1.25	0.38	1.50	0.46	No
1968	327,500	40,381	1.00	0.30	2.00	0.61	No
1969	449,200	55,386	1.33	0.41	3.00	0.91	No
1970	637,760	78,636	2.00	0.61	3.00	0.91	No
1971	415,000	51,170	1.50	0.46	2.00	0.61	No
1972	262,000	32,305	0.50	0.15	0.67	0.20	Yes
1973	433,440	53,443	3.00	0.91	3.00	0.91	No
1974	941,890	116,135	3.00	0.91	3.00	0.91	No
1975	646,400	79,701	1.00	0.30	3.00	0.91	No
1976	746,960	92,100	2.50	0.76	3.00	0.91	No

Alternative production methods, though they may be less polluting, are rejected if they are higher in cost.

The internalization of costs of pollution (economic damages resulting from pollution) is depicted in Figure 11. The curve AC_1 reflects all costs of production except for those associated with salinity in return flows, i.e., pollution, Curve AC_2 includes the pollution costs and thus lies above AC_1. The curve AR represents the price of the produce produced. The intersection of AC_1 and AR describes the quantity that will be produced, OQ, if pollution costs are unpaid. If, however, the producer is forced to internalize pollution costs, he will reduce production to OQ_2, the intersection of AC_2 and AR. The level of production OQ_1 could be maintained only if the price of the produce rose to P_2.

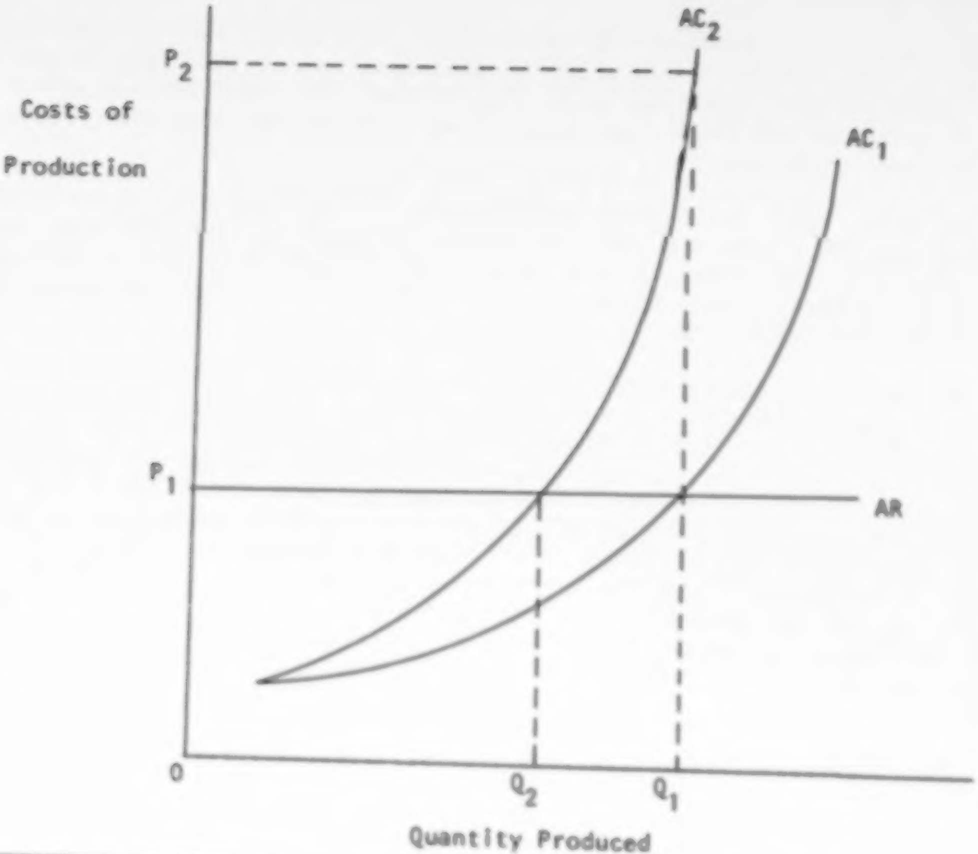


Figure 11. Costs of production of agricultural crops, with and without internalization of pollution costs.

In the project area, where opportunities to affect quality of return flows may be limited because of relatively efficient management of water, treatment of effluent may become necessary. Costs of treatment, to the level necessary for abatement of economic damages, could be allocated to agricultural water users. They would thus be forced to an internalization of the costs of pollution.

LEGAL CAUSES

Water quality problems in any form on the Rio Grande in the project area are accentuated by the legal and institutional situation that prevails. It has been stated many times previously that the explicit water quality problem from irrigation return flow exists with increased intensity as one proceeds from the Elephant Butte Irrigation District to the El Paso Irrigation District and finally to the Hudspeth Irrigation District. The physical causes discussed above occur partly as a result of the existence of irrigated agriculture in the project area and partly from nature.

But, it is very difficult to explicitly identify the legal causes to the problem in terms of their chronological contribution. From a state's perspective, it can be concluded that water laws adopted and organizations created or evolved to administer these laws have become institutionalized over time and are resistent to change.

The major legal causes, not specifically for the degraded return flows reaching the Rio Grande from Mesilla Valley, through the Hudspeth area, but contributing to the situation that exists, can be described best by delineation into the three levels of water administration--international, federal/interstate, and intrastate.

At the international level, the Treaty between the United States and Mexico on the Rio Grande requires the United States to deliver 60,000 acre-feet (7,398 ha-m) per year at El Paso-Juarez. Because the river is not only international, but interstate as well, the Rio Grande Compact calls for a division of the remaining waters between Colorado, New Mexico and Texas. This Compact also has reference to minimum water quality conditions to be met by Colorado in delivering water to Texas and New Mexico. These two agreements do not in themselves cause an irrigation return flow problem, but they do set the parameters for reallocation of water in the basin. Also, these agreements may become the basis for future action modifying upstream activities should water of unusable water quality be delivered to downstream users.

The intrastate level of water law provides the breeding ground for possibly creating water quality problems from return flows. It is at this level, under normal circumstances, that water is allocated to various uses and standards for use prescribed. Both New Mexico and Texas have adopted the prior appropriation doctrine for surface water allocation with the requirement that water be put to beneficial use and waste of water prevented. Ground water allocation is by prior appropriation in New Mexico and absolute ownership in Texas. The difference between these two ground water doctrines and the lack of coordination between the two states has been an inducement for water users on each side of the state boundary to use as much ground water as possible.

But the Rio Grande case study area is not the normal case for the western United States, and from a legal perspective, the difference is significant. As opposed to the normal situation where individuals, companies or districts in the downstream state appropriate water under this state law with points of diversion in their state, the El Paso Irrigation District in Texas and the Elephant Butte Irrigation District (IBID) in New Mexico have a common point of diversion located at Elephant Butte Reservoir in New Mexico. Texas' share of water in the Rio Grande is measured at Elephant Butte. Also, both districts were federal reclamation project areas with the Bureau of Reclamation being record holder of the water rights for the districts. EBID has repayed its construction costs and the Bureau has conveyed the title to these water rights to the District. So, federal reclamation law is also involved in governing how water is allocated to certified land.

In New Mexico, the State Engineers Office feels it has no right to tell farmers in Mesilla Valley what to do with their water because there has been no legal adjudication of the river. This office sees as its duty, however, to initiate or promote better water management and oversee the exercises of the water rights.

With regard to quality of water, both New Mexico and Texas prefer that irrigation return flow be designated a nonpoint source. The Water Quality Commission in New Mexico stated:

> ...it is (their policy) to consider as acceptable degradation those minimal concentrations which result from the return weight of the constituents diverted (Rio Grande Basin Report, Water Quality Commission, p. 1-2, Sept. 1975).

This policy is based upon a provision in the 1973 Water Quality Act which states:

> The Water Quality Act does not grant to commission or to any other entity the power to take away or modify property rights in water, nor is it the intension of the Water Quality Act to take away or modify such rights...if, in the adoption of regulations and water quality standards, and in any such action for enforcement of the Water Quality Act and regulations adopted thereunder, reasonable degradation of water quality resulting from beneficial use shall be allowed (N.M., Sec. 75-39-11).

The situation in Texas is similar. The NPDES program has not been adopted, and under the Texas Water Quality Act, agricultural wastes except tailwater and runoff water can be controlled.

Thus, the legal frameworks for water allocation and water quality control do contribute to the overall concerns for water use in the case study area, but do not in themselves act as a legal cause of the water quality problems examined in the lower portions of the Valley.

SOCIAL CAUSES

Throughout any discussion of social causes of the irrigation return flow quality problem, one generally focuses on the cluster of social conditions that facilitate or aggravate problems of water use and return. These conditions must be seen at two different levels: at the micro-level--referring to the individual farmer, his motivation for effective management, or capabilities for conducting everyday operations; and, at the macro-level--or the organizational network and system of institutions and procedures surrounding water quality management.

Thus, the problem of water quality exists in a social setting either because individuals are not in agreement as to the nature or characteristics of the problematic situation (or are unable or refuse to do anything about it);

or, entities involved in and responsible for irrigation management cannot (or do not want to) be mobilized or respond to irrigation management challenges.

The Individual Level

At the individual level, there are three general categories to which water quality problems can be traced: a) the perception by the individual of the problem; b) the actual irrigation activity pursued by the farmer; and c) the perception of the farmer regarding his relationship with his neighbors in terms of water quality. The basic point is that how individual users behave within such categories will also determine how the problem is to be defined and how responses for coping with it can be delineated.

As a whole, the farmers in the area are well aware of the salinity problem. They are also cognizant of the fact that they must leach these salts from the soils (to the extent that they are doing it now) if their lands are to remain viable. Thus, the overriding question has to do with the problem of what is going to happen with the salts. In this regard, the critical concern of the farmers has to do with the variety of alternatives proposed for the removal and disposition of salts. Given the limited water supply, there is a particular dilemma in defining a problem whose nature is dependent on appropriate solutions, i.e., from further dilution which increases downstream problems. But this perception is more true in the El Paso and Hudspeth Districts, rather than in the Mesilla, where the problem is not considered significant.

Concerning actual irrigation activities, the people in the area are generally concerned with the quantity of water allotted to them. There is a general belief or feeling that farmers are managing their limited water supply quite well. Instances of mismanagement are usually passed off with a reference to undependable hired labor. There is little concern expressed about the quality of water they use.

Finally, it is evident that there is only limited recognition of the problems of saline return flows and degraded river water. Many of the farmers on the New Mexico side of the project view Texas' water quality problems as just that--Texas' problems. The variations in perceiving quality problems can be seen in the difference of opinion among users within the Elephant Butte Irrigation District. For example, farmers in the northern part of the district resist the use of underground water, while those in the south favor such an activity. In addition, it has been indicated that the District's proposed rehabilitation project costing approximately $100 million will meet with widespread resistance among farmers in the area. A lot of individual farmers are doing their own on-the-farm improvements when they have the capital rather than waiting for outside assistance or any collective approach. In this respect, then, there seems to be a strong sense of individualism which, in the long run, affects various implementation strategies.

The Organizational Level

Regarding the organizational entities involved with irrigation management in the area, two categories of concern are related to water quality problems in irrigation return flow: a) the extent of integration of all such organizational units within each state; and b) their respective authority with regard to irrigation water quality.

As stated before, it is within the general organizational structure that broader normative standards of behavior regarding irrigation return flow can be established, which in turn can help change various perceptions by individual users regarding the nature of the problem as well as efforts for coping with it.

As far as the first point is concerned, the integration of organizations and coordinated action are based heavily on the degree and type of communication between the various units or entities. Generally, in the Rio Grande the overall communication among area leaders is excellent. The two large districts realize the degree of interrelationship among them and are constantly informed about the other's actions. In addition, RIGREP provides the mechanism for generating a regional concern with regard to various issues. Thus, there does exist at least the institutional framework for a comprehensive regional irrigation policy. Such a framework cannot only coordinate policies and activities, but can also act as an important "gatekeeper" with respect to mandates from sources outside the region.

The effectiveness of communication between the leadership and the individual farmers is difficult to assess. Yet, this effectiveness is of critical concern in the implementation of any given alternative because general acceptance of any alternative is necessary to implementation. It is interesting to note that the governing boards of the irrigation districts have been occupied by only a few district members. Similarly, Soil Conservation District Boards and Agricultural Stabilization and Conservation Committees have attracted only a few farmers--apparently recognized leaders. These people enjoy the confidence of their community members and can communicate effectively with them. Their relationships constitute a communications network that is the important backdrop against which water quality control alternatives or measures will be assessed and ultimately accepted.

As to the authority structure of the organizational set characterizing the area, a mixture of federal, state, interstate, and international agreements complicate the situation. For example, New Mexico has not adopted the NPDES program while Texas has done so, but not implemented so far. On the other hand, New Mexico has adopted a reasonable water degradation policy which applies to agricultural uses and discharges of water, while other states have not legislatively recognized the natural impact of water use in agriculture.

On the broader level, the complexities of the situation that give rise to a series of social "causes" to irrigation return flow quality contain also number of other interlocking factors. New Mexico and Texas are looking quite carefully at Colorado's Closed Basin Project in order to make sure that water is not degraded beyond compact requirements. One should also keep in mind the existing rural-urban differentiations and trends. In this regard, EBID has already repaid the construction cost and the Bureau of Reclamation has assigned the water rights to the District. Thus, EBID has a flexibility in policy since water is reallocated. But in El Paso, the District must have the Bureau's approval before any allocation or reallocation takes place. This lack of flexibility in the latter case is also accentuated by the trends of rapid urbanization which will change the return flow patterns (with as yet unknown long-range consequences).

The international implications are not yet a major issue because the problem of water quality has not been specifically addressed in the study area. It is indicative of forthcoming conditions, however, that in the lower Rio Grande the discussion on water quality has consumated into an agreement on salinity control between the two countries and, thus, precedents have been established.

An important point is also the role of migrant labor as it relates to problems of water quality. While seemingly remote to the problem at hand, we are facing a situation of cheap labor and of relatively inexperienced farmers. Thus, it is more cost-effective to hire cheap labor and pay more for water, rather than concentrate on costly water effective on-farm management.

Such a plethora of interacting factors--local, state, interstate, and international--as well as the basic belief that farmers should be allowed to do as they please with their allotment of water, all add up to a complicated network of causes contributing to return flow problems. It is important, therefore, to proceed here with a systematic identification of potential solutions.

SECTION 7

IDENTIFICATION OF POTENTIAL SOLUTIONS

PHYSICAL SOLUTIONS

Because of the long-time interest of engineers in problems and opportunities for water development, it is logical to think first of physical solutions to water quality problems. But there are economic, social and legal solutions which may be just as acceptable and as cost effective. These will be examined in turn.

Augmentation of Water Supplies

An obvious means of improving the quality of water in the study area is to increase the total quantity of water of good quality. To this end, it will be important that Colorado deliver annually the quantity of water which is its Compact obligation. Additional quantities will be hard to locate but might be created via weather modification in the headwaters of the Rio Grande, or by importation from other areas, e.g., from Texas via the transport system of the Texas Water Plan.

An additional source of water is the Santa Fe aquifer which underlies the alluvium of the Rincon and Mesilla Valleys and yields high quality water. Already the Elephant Butte Irrigation District has drilled five wells in the aquifer and pumps the ground water into project canals. More wells are planned. The El Paso Valley would appear less fortunate in that known ground water reserves are of a poorer quality than project water.

Infestations of phreatophytes in the Rio Grande Basin in New Mexico above Caballo Reservoir are estimated to total 54,900 acres (22,235 ha), with particularly extensive concentrations being located in the vicinity of San Marcial. Plans by the USBR to eradicate extensive stands of phreatophytes would salvage an estimated 34,700 acre-feet (4,279 ha-m) of water per year (USBR, 1971). Evaporation losses from Elephant Butte and Caballo Reservoirs are estimated to be 254,800 acre-feet (31,417 ha-m) per year (New Mexico State Engineer, 1967). Future developments in evaporation suppression could possibly prevent a significant portion of this evaporation.

The highest measured TDS concentrations of inflowing water to the Rio Grande are those of Galisteo Creek, Rio Puerco and Rio Salado. Higher salinity levels may exist in other ungauged tributaries, but these have a lower annual discharge and hence a smaller load. The loading from saline tributaries could possibly be prevented by diverting or damming the tributaries and allowing the impounded water to evaporate so that the saline water never reaches the river. Another alternative which will likely become more feasible in future decades would be desalination.

Water Delivery Subsystem

The quality of water delivered to the El Paso Valley and to Mexico is worse than that delivered to the Rincon or Mesilla Valleys. This is because of return flows which increase the salinity of the river water. It would be desirable to provide water of equal quality, and for this purpose a reservoir could be constructed in an arroyo above El Paso and filled during the non-irrigation season using the conveyance facilities of the upper two valleys for the most part. Alternatively, if the main canals from Percha Dam to El Paso were lined on the existing cross-section, they would have additional capacity in which to carry the water supply for the El Paso Valley and Mexico in addition to that for the upper two valleys. The El Paso Valley and Mexico could be provided with water of identical quality to that of the Rincon and Mesilla Valleys, rather than by relying largely on return flows. This alternative would avoid the cost of building a dam, and could be carried out as part of rehabilitation of conveyance facilities of the upper valleys.

Rehabilitation of the facilities of the Elephant Butte Irrigation District has been planned, although the implementation of the plan is uncertain. The so-called "Archer Plan" envisages the main canals being concrete lined and the laterals being enclosed in concrete pipes. The main objective of this plan is to allow better water control while reducing operation and maintenance costs. Seepage would also be reduced. By allowing water to be delivered in the right amount at the right time to the farms, improved irrigation methods and practices would be possible, thereby allowing more effective use of a limited amount of water so that the necessity of additional water supplies from ground water can be minimized.

Rehabilitation of the facilities of the Hudspeth County Conservation and Reclamation District No. 1 would go a long way towards allowing better use of the resources which they have available. In the valleys about it, water lost through seepage returns to the river for use downstream. Water lost through seepage in the Hudspeth District is lost from the system. Lining of canals and laterals would prevent much of this loss.

Regulating reservoirs within the Hudspeth District are very shallow and serve more as evaporating ponds than as useful storages. Regulating reservoir No. 1 could be substantially deepened and still be drained of its supply. This would allow full use of arroyo inflow to the system which occurs intermittently during the summer, which also provides the highest quality water available to the district. The possibility exists of damming some of these arroyos for conservation storage for the district.

Some effect on water quality within the study area could most likely be achieved through a modification of irrigation practices. To implement an effective irrigation scheduling program so that maximum yields can be achieved with the available water supplies requires that flow measurement structures be provided at all farms in order that farmers know exactly how much water is being applied. Timing of applications becomes critical. An examination of water delivery records indicates that heavy water applications are being made early in the season for germination and to promote leaching. This is desirable to lower the salt concentration of the seed bed in readiness for germination. Generally, as the plant grows it can tolerate more saline conditions. However, an examination of drain flow records also indicates that the amount of water being applied during early season leaching is far in excess of that required to leach salts below the ultimate root zone. The water lost from the soil is transported downstream for reuse, rather than the downstream users obtaining better quality water from storage.

Research is currently underway to determine the viability of applying sufficient water to leach salts only immediately beyond the root zone. Salts could be stored in the soil below the root zone for an indefinite period until high flows are available, when they could be leached and removed from the system. This concept requires good water control and is probably best suited to methods such as trickle irrigation. The large acreage of pecans in the study area would be well suited to this method of irrigation. Trickle irrigation would also result in lower consumptive use, thereby leaving more water in the system.

As discussed previously, return flows have a higher salt concentration than the applied water due to the concentrating effects of irrigation activities. River water quality could be improved by eliminating return flows altogether, by preventing return flows from reaching the river, or by purifying drain flows before returning them to the river.

The elimination of lower quality return flows would require complete system rehabilitation so that very little, if any, water was lost by seepage from the conveyance system, as well as modification of irrigation methods and practices so that water was applied in quantities sufficient only for plant needs plus a minimum leaching requirement. This alternative requires a very high level of water management, higher in fact than is presently being achieved on any irrigation project in the United States.

Return flows could be prevented from reaching the river by diversions from the drains and evaporation in impervious reservoirs. Periodic salt removal would be necessary. A large land area would be required under present practices to provide sufficient storage for the high volume of drain flow. A modification of irrigation practices would reduce this flow volume.

Purification of drainage water could be accomplished by desalination. Desalted drainage water from the Rincon and Mesilla Valleys could be mingled with water released from storage for delivery at the El Paso Valley and Mexico. Some improvement in the quality of drainage water could also be accomplished by the eradication of phreatophytes within the study area. These phreatophytes presently concentrate the salts in the return flows as a result of evapotranspiration.

ECONOMIC SOLUTIONS

Expanded Water Transfers

Though water is used with comparative efficiency in the project area, there are possibilities for improvement. Two economic measures in particular offer some potential for increasing efficiency in water use. One is a greater use of the water market mechanism which now exists within the project. The other is a tax-subsidy plan to force internalization of pollution costs.

If water transfers, via sales of all or portions of allotments, were to become more prevalent in the entire project, efficiency in the use of this scarce resource would be facilitated. Water would be employed in the higher-valued uses, the cost of a unit of water would go up, and a more conservative use of the higher priced input would be stimulated. The aggregate supply curve, in Figure 12, would be changed from S_1, where it reflects only the conveyance cost, to S_2, where it reflects (at least partially) opportunity costs. Users would respond by reducing their use of water on low value

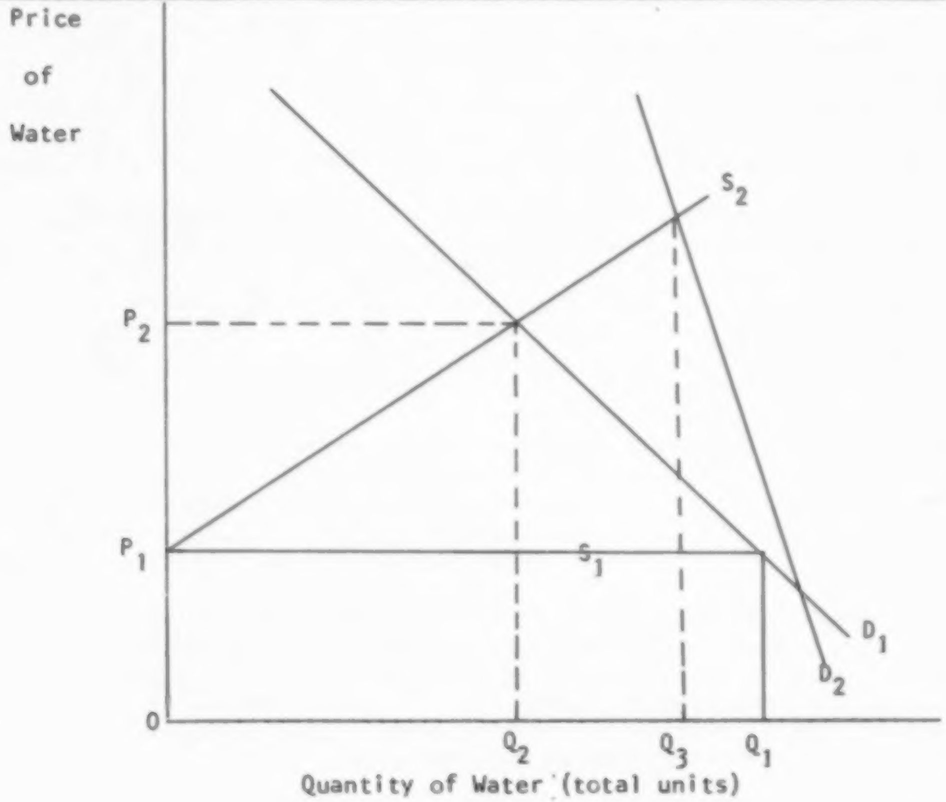


Figure 12. Demand for and supply of water with and without water transfers.

crops, and they would probably change the mix of crops irrigated to make optimum use of the higher priced water. The demand curve would change from D_1 to D_2 to reflect the changed use of water so that the new equilibrium price would be P_2. Thus, a more efficient use of water would be realized. Its value-in-use would be increased, and its employment in crop production would be improved by the more careful application of the higher-priced input. Quantities of water applied would be carefully matched to the needs of crops being irrigated plus requirements for leaching salts from the soil.

Pollution Taxes/Treatment Subsidies

An improved allocation of water among agricultural uses would certainly be helpful to water use and to improved quality of return flows, but it would not be sufficient to correct the problem of increasing salinity of the river. For the farmer is still able to dispose of the relatively saline return flows without costs. There is no internalization of the costs associated with the polluted water. A pollution tax could be employed to cause the internalization of this cost. It would be levied so as to approximate the cost of reclamation of water to required or desired levels. Proceeds from the tax would then be used either to treat the effluent (the return flow) or to develop influent controls, such as improved distribution systems, improved irrigation systems, improved cultural practices, etc. The exact form and level of a tax can be specified only for particular cases.

In Figure 13, the cost of water, with the pollution tax, is S_2. It is presumed that the tax increases with additional increments of water used per acre of land because return flows would increase and treatment costs would also increase. The quantity of water used would be reduced from Q to Q_2 because of the higher cost of water. The demand curve might also shift, as in Figure 12, but that is not suggested in this example.

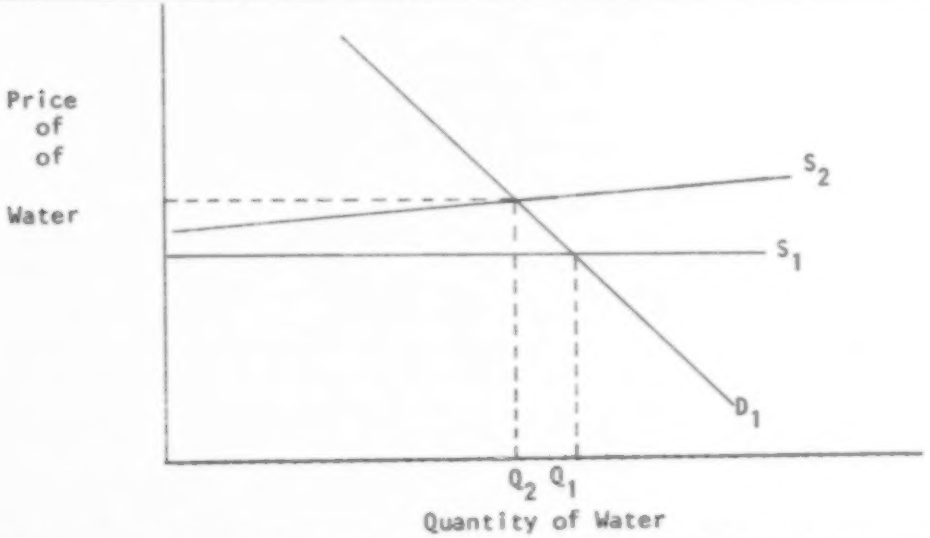


Figure 13. Demand for and supply of water with and without a pollution tax.

It may be desirable to improve the tax at a level somewhat less than the pollution cost. The subsidized water management practices and capital improvements could benefit not only from the proceeds of the specific pollution tax, but also from other tax revenues. The judgment of the Congress or of state legislatures would be necessary to such decisions. But the notion of penalties and rewards, i.e., taxes and subsidies, to reduce pollution of water used in agriculture is useful and should be included among the alternative solutions to irrigation return flow quality problems.

LEGAL SOLUTIONS

To the extent that the law has contributed to and can induce or direct changes in the water use patterns in the case study area, a number of solutions are proposed. The first is directed to the water allocation laws. Texas has a provision which allows the Water Rights Commission to curtail or abate water diversions where there are discharges or returns of water which are in violation of the water quality standards. This is a condition in the granting of the water right. New Mexico could benefit by such a provision in its water rights laws.

The recognition of reasonable degradation from beneficial use found in New Mexico law would be very useful to Texas water users. The adoption of criteria and standards for beneficial use would be reasonable additions to the law in both states. Such criteria and standards would give the state agencies a strong legal basis for curtailing overapplications of water where proof of unreasonable degradation to receiving waters exists.

To date, the IBWC has not explicitly examined the salinity situation of the Rio Grande in the El Paso-Juarez area. However, precedent does exist on the river for some improved management direction coming from the international level if and when the problem reaches such significant proportions. Under Minute 223, entered into between the United States and Mexico on November 30, 1965, measures were agreed upon for resolving the salinity problem in the Lower Rio Grande. The problem of salinity occurred from irrigated lands. Among the solutions were dilution, by-pass channels and regulations of discharges into the river.

The solution considered most viable under existing legal, economic and social conditions is to improve the means of water delivery and application through voluntary or induced influent control. Although the problem is one of concentrating effects due to out of stream diversions rather than salt loading, more judicious approach to water delivery and use should enable greater coordination and cooperation between and within the three irrigation districts involved.

SOCIAL SOLUTIONS

Solutions or answers to problems of irrigation quality control from the social standpoint evolve from the varied social circumstances and interactive conditions that allow such a state of affairs to exist in the first place.

Therefore, and in relation to the points raised in the previous section, possible solutions, affecting changes or producing responses to return flow problems must have two points of reference: the individual user and the organizational network.

The Individual User

In order to initiate responses by the farmer with regard to various irrigation return flow alternatives, such individual users must be made aware that there is indeed a problem. Attempts should be made to inform users about sources and characteristics of the water quality problems and about alternative solutions which are potentially "implementable."

Also, efforts should be made to involve the farmers more into the affairs of their district and particularly with the work of RIGREP. Through such efforts the individual water user can see what is happening on a regional basis and at least become more sensitive as to the overall aspect of water use.

The above point is particularly important in view of the fact that districts should be concerned not only with distribution, but also with water management. In this regard, then, the individual user should become aware of what other functions can be served by the district other than simple distribution of water. This implies extensive communication links between water users and state or federal quantity and quality control agencies, other than annual meetings (such as, e.g., announcements, newsletters, TV spots, etc., which provide for more extensive and/or frequent means of communication).

The Organizational Setting

No matter how much emphasis one places on the individual, if the organizational part of the social system does not support such an effort, then the effectiveness of individual programs will be rather limited. RIGREP, with its advantageous position, should encourage further activity dealing with water quality problems and help coordinate all of the appropriate material regarding water quality management.

It is important, at this point, to distinguish between state agencies and local/regional districts. The first have the responsibility of carrying out the mandates of the law on a statewide basis. Thus, in a specific situation they may not be particularly sensitive to local conditions, as they try to encompass quite a variety of diverse circumstances. Finally, here, regional organizations must also have a more accurate knowledge of their purpose vis-a-vis irrigation return flow quality control.

Recognizing the advantages and disadvantages of linking various levels of organizational units, the overall conclusion remains one of improving active participation in decision-making. For instance, one could easily envisage a faster change in Board personnel, so that alternatives and solutions could be scrutinized by a larger segment of people and of entities involved in irrigation.

In summary, solutions emphasizing a sociological approach include:

a. preparation and distribution of comprehensive information packages dealing with water management of the Rio Grande;

b. more active involvement of farmers and of water users in the affairs of the irrigation districts and of RIGREP.

c. allowing and encouraging RIGREP to play a more active role in water quality problems of the area;

d. strengthening of the communication linkages between officials and users, even to the extent of individual users being active participants in the decision-making process.

COMBINATIONS OF SOLUTIONS

It is obvious that no one alternative solution will suffice in our struggle to solve or at least materially alleviate the problem of degradation of quality of water used in irrigated agriculture. It also seems obvious that no solution or combination of solutions can be implemented which will entirely solve the problem of polluted return flows from agricultural lands. Some degradation of quality is inevitable if water is used in agriculture. There will be some increase in salinity, some increase in sediment, some increase in other foreign materials simply because water has been combined with soils, fertilizers, seeds, and other inputs in agricultural enterprises. We must recognize this inevitable impact on water quality and find the acceptable "trade-offs" which will allow water to be used in agriculture.

Implementation of some of the technologies suggested for water transfer and distribution systems, irrigation systems, and drainage systems will require cost-sharing programs, subsidies to induce investment in the technologies. This sort of subsidy has a long history in agriculture. Most of our conservation programs have included an element of subsidy. A pollution tax might be employed to raise some or all of the revenues necessary for the subsidies. There are examples of "user taxes" in our society which are employed for specific purposes, e.g., the gasoline tax is used to build roads. A tax levied against polluters of water could be just a use tax, which would represent a fraction of the pollution cost, or it could be a tax imposed on the basis of the pollution. The latter would require a system of monitoring of return flows which might be prohibitively expensive. The technology for such a system is not fully developed.

Changes in water law to reflect the new or changed conditions surrounding water use would have "spillover effects" which might require changes in economic institutions. If the water right is redefined to include responsibilities for maintenance of quality, it may be necessary for the public to assist rights holders with capital investments to safeguard quality. Such assistance could be a subsidy, e.g., a low interest loan, cost-sharing on improvements, accelerated depreciation of equipment, etc.

Expansion of a water market in the Rio Grande Project might take us a quarter, or half way toward our goal of improved water quality. So it would be necessary to add to this alternative solution some physical improvements in distribution systems, some new irrigation techniques, and a cost-sharing arrangement to finance this "hardware." We might add a new canal for transporting water to a holding reservoir new El Paso. This would be a federal project, involving loans, borrowed technology, etc.

The combinations of alternative solutions are finite, but very numerous. Development of the combinations will require imagination, analyses, evaluation and finally decision about what is "best." The final section of this report is given to evaluation of solutions and combinations of solutions which are appropriate to the Rio Grande Project.

SECTION 8

ASSESSMENT OF POTENTIAL SOLUTIONS

Following the identification of potential solutions for return flow quality problems in the Rio Grande Valley, attention was directed to assessment of these solutions. It was presumed that alternative solutions would be more or less acceptable (and thus implementable) depending on their impacts on the affected persons. Testing procedures were devised to determine technical, economic, political, and social acceptability of alternative solutions. They involved: 1) the project team; 2) state and federal agency personnel; 3) irrigation water managers; and 4) water users.

The first evaluation was done by the project team. Composed as it was of engineers, economists, sociologists, and an attorney, the team was able to judge alternative solutions in terms of technical, economic, legal, and social feasibility. Obviously inappropriate and ill-advised solutions were weeded out, though the number was not great. Alternatives with potential for significant impacts on the quality problem and those without prohibitive costs remained for further evaluation by others. The team wished to present the widest possible range of alternatives to succeeding evaluators.

A second evaluation was accomplished by federal and state agency personnel, chiefly those presently or prospectively involved in administration of quality improvement programs. The alternative solutions were thus screened by those with technical and legal expertise, a group with a special concern for administration of laws and programs. This group tended to sort out those solutions which did not fit within the framework of existing laws, rules and regulations and which would therefore be difficult to implement. The list of alternatives was reduced, but not so as to exclude some solutions which would be possible with changes in laws, rules and regulations.

The third evaluation was completed by managers of water supply agencies (e.g., irrigation companies and districts) and their boards of directors. These were individuals having responsibility for distribution of water among farms of members and patrons and for maintenance of system facilities. Because they are potentially responsible for administration of revised rules governing diversions and use of water, they tended to resist measures of control. But they were aware of water quality problems; they were generally convinced of possibilities for improved use of water; and they tended to favor quality control measures located and administered at their level rather than at higher or lower levels.

Finally, the fourth evaluation was done by users of water, i.e., farmers who use water in irrigation crops. They were interviewed one at a time; there was discussion of the return flow quality problem; and potentially useful solutions were outlined and discussed. These individuals, though alarmed by present efforts to control their use of water, showed both ability and willingness to comprehend problems of water quality and deal with them. They were very practical in their judgments of implementability of the various alternative solutions, and they tended to favor those measures aimed at improved use of water in agriculture. It was these measures over which they had some control.

The alternative solutions proposed for evaluation ranged from those which were wholly technical (e.g., rehabilitation of distribution systems) to those which were institutional (e.g., creation of water markets). The technological alternatives were classed as: 1) those which would increase the volume of available water; 2) those which would control salinity; 3) those which would improve distribution of irrigation water; and 4) those which would improve water management on farms. The institutional alternatives were classed as: 1) those affecting water rights; 2) those affecting water transfers; 3) those limiting pollution discharges; 4) those providing incentives for improved water management; and 5) those providing for education and technical assistance. A summary of the alternative solutions and the evaluation of them by the project team is in Table 12.

EVALUATION BY THE RESEARCH TEAM

The research team, composed of several disciplines relevant to the return flow problem, reviewed the alternative solutions in terms of effectiveness in solving the problem and prospective implementability. The team was assisted in its evaluation by knowledge of on-going research at New Mexico Agricultural Experiment Station, by earlier contacts with RIGREP members, district managers and others in the area, and by their own experience in water supply management and use.

Water Source Improvements

Additional sources of high quality water would improve existing water quality by dilution. The remaining lower leaching requirement would allow a potential reduction in the salt pickup from the irrigated lands.

The provision of additional water could come through a number of measures. The implementation of some of them may depend on a number of factors apart from water quality considerations. Three such measures include Colorado's fulfillment of her Rio Grande Compact obligations, the Texas Water Plan and weather modification in the upper Rio Grande. All of these measures would tend to improve water quality in the study area. However, this is only one of the factors to be considered amongst the several issues surrounding them.

The Rio Grande Compact has been a water-sharing agreement about which there has been controversy for several years. Colorado has been charged with

TABLE 12. SUMMARY OF TECHNOLOGICAL AND INSTITUTIONAL ALTERNATIVES APPROPRIATE TO IMPROVEMENT OF IRRIGATION RETURN FLOWS, MIDDLE RIO GRANDE PROJECT

	PROBABLE EFFECTS			
Technological Alternatives	Water Quality	Economic	Legal	Sociological
I. Increase flow of the river, expand volume of water.	-If increased flow is left in river, then concentration of salts will be reduced. -If increase flow is diverted then the effect on the concentration of salts will not be significantly different from the present situation.	-Higher quality of water from flow in the river would increase crop yields and agricultural income. -Make more water available for irrigation if increased flow is diverted.	-Increased flow cannot be left in the river until all existing appropriations can be met. -If existing appropriations cannot be met, the state may appropriate the increased flow for in-stream water quality improvement.	-If increase water is used for agriculture, the rural farm population will become more stable. -Greater flow of water may enhance the urbanization of the area. -Depending on the amount of increased water, attitudes toward the use of water, district improvements and district authority will change.
I.A. Supplement river flow via pumped water.	-Most of the existing water is pumped from the shallow aquifers, which tends to be of lower quality.	-Mining the water at a rate greater than the recharge may bring high returns in the short-run, but would eliminate ground water reserves that allow the farmers to stay in business in water-short years.	-Potential interference with existing wells. -Would permit more consistent diversions to junior rights holders.	
I.B. Induce precipitation and runoff via cloud seeding.	-The effects of cloud seeding depend on the amount of water generated.	-Still an experimental technology and it is not clear that benefits exceed costs.	-Cloud seeding efforts in one area may cause liability for damages in another area. -Would permit more consistent diversions to junior rights holders and allow for new appropriations.	-Some interstate agreement must be established as to the consequences of such a program. -Environmental objections may be a problem.
I.C. Eradicate phreatophytes above Caballo Reservoir.	-Could save 34,700 acre-feet of water. Lower concentrations below Caballo from 500 mg/l to 480 mg/l.	-Costs of control would have to be borne by beneficiaries, but a subsidy might be arranged to provide a public input into the project (B/C ratio, USBR 4.63:1).	-Again, this would provide more consistent diversions to junior rights holders.	-Resistance by users may occur in having to pay the costs. -Environmental and aesthetic objections will arise.

(continued)

TABLE 12 (continued)

	PROBABLE EFFECTS			
Technological Alternatives	Water Quality	Economic	Legal	Sociological
I.D. Suppress evaporation from the reservoirs.	-Some 250,000 af (35,825 ha-m) of water is now lost via evaporation; but technology is not yet developed. -If 100,000 af (12,330 ha-m) of water is saved it will lower the concentration below Caballo to 435 mg/l. -If 200,000 af (24,660 ha-m) is saved, it will lower concentration below Caballo to 350 mg/l.	-Technology is not yet developed; costs would be prohibitive.	-For this to be a successful solution to IRFQC, it would be necessary for the Rio Grande Basin states to obtain authority to appropriate the increased flows in the name of the state. Otherwise, unappropriated waters may be filed upon.	-Methods in suppressing evaporation will interfere with recreation pursuits in reservoirs.
II. Impound flows of highly saline tributaries.	-Reduce salt load and concentrations by keeping saline water out of river. Lower concentration at San Marcial from 460 mg/l to 440 mg/l. -However, loss of 66,000 af (8,135 ha-m) of water per year.	-Costs of improvements to evaporate these waters would be considerable; costs would probably be shared. Improvement in water quality of 20 mg/l is only a small benefit to downstream users, while the cost and decrease in total flow is high. -Water in tributaries is of a higher quality than Hudspeth Co. now receives.	-Reduction of volume flows may have adverse impact upon vested rights giving ground for legal action if it can be demonstrated that there is sufficient dilution to provide useable water qualities.	-The critical point will be with loss of the water. Farmers with junior rights may be significantly affected. -This action may affect the interstate agreement on delivery of a specific quantity of water.
III. Provide aquaduct from Caballo to El Paso and possibly beyond.	-Provision of water at 500 mg/l throughout the system instead of the current 800 mg/l at El Paso and 1500 mg/l at the County Line. Would provide water of equal quality to irrigated lands in Mesilla and El Paso Valleys. -Adverse environmental effect on fish and wildlife.	-Would be a costly means of improving the quality of water delivered to Texas, but would provide a supply of water equal to that used in Mesilla Valley. -Existing constraints on crop production in the El Paso Valley would be eliminated. Crops of higher value could be produced. -Effect on gross income from agriculture could be an increase of 40% in the El Paso Valley. Would probably cost $100 million (rough estimate). If 40% increase in gross agricultural income, then benefits would be: for 25 years @ 6%, $103.54 million.	-Legal effect may be interference with vested water rights of the districts at increased cost without significant benefit to either EBID or EPID.	-There will be a new interorganizational relationship between the USBR (if they build it) and irrigation districts. -Will there be new management problems?

(continued)

TABLE 12 (continued)

Technological Alternatives	PROBABLE EFFECTS			
	Water Quality	Economic	Legal	Sociological
IV. Improve distribution systems in irrigation districts.	-Effects on water quality would come principally from allowing better on-farm management. If water supplied on demand, may eliminate pumping of some low quality ground waters.	-Would increase efficiency of water diversion and distribution, save some water for use on crops. -These improvements may be very costly, as evidenced by a proposed $108 million project for EBID.	-Greater achievement of states' beneficial use concept, only possible adverse effect may be reduction in amount of water divertable under existing rights.	-The irrigation districts will have greater control over water. -Critical consideration is the persuasion of the district member that the program is needed.
IV.A. Line canals and put laterals in concrete pipe.	-Would reduce seepage loss. -Any practices or improvements which cause surface water to be used more efficiently result in: 1) decreasing percolation which decreases the ground water reservoir; 2) decreasing concentration of salts in the river, & increasing concentration of salts in the land.	-Would increase investment in facilities and thus increase capital costs of water systems, but would lower annual operating costs.		
IV.B. Install flow measuring devices.	-Would permit accurate deliveries of water to farms for better on-farm management.	-Would allow accurate measure of water applied to crops; greater efficiency should cause reduction in costs of production.		
IV.C. Deepen regulating reservoirs of Hudspeth County C&RD, construct reservoirs on arroyos.	-Reduce evaporation and concentration of salts. -Capture wild water.	-Would reduce evaporation and concentration of salts; make more water available for irrigation, increase crop production and increase gross income. -This may have significant benefits in allowing Hudspeth Co. to capture more water for irrigation.		-Uncertainty of water supply may cause an aversion to investment in storage facilities.
V. Modify irrigation practices.	-At absolute best, make water quality downstream equal to upstream (500 mg/l at Caballo). -However, with a lower leaching fraction, the concentration of leachate will increase so that the loading will not decrease in proportion to the decrease in quantity of return flow.	-Would improve on-farm management of water.	-Positive legal effects as water users improve water use efficiency.	-Will require technical and perhaps financial assistance. -Educational program necessary for implementation.

(continued)

TABLE 12 (continued)

	PROBABLE EFFECTS			
Technological Alternatives	Water Quality	Economic	Legal	Sociological
V.A. Implement an irrigation scheduling program.	-Lower leaching fraction would reduce loading of river where it is occurring.	-Would provide for application of water according to plant requirements and increase crop production.	-Must consider rights to divert	
V.B. Make some changes in irrigation methods and practices.	-Same as III.V. above. -Also trickle irrigation is well adapted to some crops, e.g., pecans, and would permit reductions in water used.	-Changes in irrigation methods would involve new investments and would thus increase costs of production.		
VI. Divert return flows in drains to evaporative ponds or desalinization plants.	-Would keep highly saline water out of river and reduce salt load. -Problem of brine disposal.	-Construction of ponds would require investment of public and/or private funds; impact on irrigated agriculture would depend on cost-sharing arrangement.		-Organizational task rearrangement will ensue. -An additional work relationship between the USBR and the irrigation districts will ensue. -Resistance by users to the costs that will be levied may occur.

(continued)

TABLE 12 (continued)

Institutional Alternatives	PROBABLE EFFECTS Water Quality	Economic	Legal	Sociological
I. Implement a discharge permit system (quotas)	-With appropriate monitoring of return flows, this would maintain the river quality at a prescribed level.	-Could significantly affect agricultural output by limiting the use of water. Extent of use will depend on water quality standards set for the river.	-N.M. has not adopted the NPDES program & consequently the federal program would have to be enforced by EPA. -New regulations for controlling discharges are proposed by the N.M. EIA that would require a "discharge plan" not a permit. -Texas has adopted a NPDES program.	-Can a permit system be implemented in the Rio Grande? Resistance is likely to be overwhelming. Numerous suits will undoubtedly be filed contesting the administration of the law.
I.A. Issue permits to the highest local water management authority.	-Would allow discharges to vary as allocations vary.	-Requires precise measurement of each irrigator's pollution discharge. This is financially if not technically unfeasible.	-No legal effect, positive or negative. -Consideration would have to be given whether this permit would be tied to the water right.	
I.B. Issue permits to individuals who are users of water.	-Would establish an upper limit on discharges.	-Would establish a limit of discharges which would be independent of water applications. -The permits or quotas will require improved management of water in irrigation methods, ditch lining, etc., which will be costly. -New investments and higher costs will be required.		-Can the individual be motivated to comply with such a system?
II. Initiate charges (taxes) for effluent, to reflect quantity and quality of return flows and costs of treatment.	-Make monitoring of return flows necessary and subsequent water quality would depend on level of taxes and/or treatment.	-Would require water users to pay the costs of pollution, i.e., the costs of treatment of degraded return flows. -Refer to Statement III.	-Similar programs for M&I discharges have met successfully the legal challenged of constitutionality. -Must be able to identify pollution and the source to satisfy the legal questions.	-What organizational mechanism will be employed to implement this program; i.e., who will monitor the effluent & levy the taxes? -What will be the degree of the resistance by farmers?

(continued)

TABLE 12 (continued)

Institutional Alternatives	PROBABLE EFFECTS			
	Water Quality	Economic	Legal	Sociological
III. Develop incentives for management/ control of irrigation return flows.	-Depends on the level of management and of control.	-Would induce water users to control distribution and use of water.	-Would permit greatest achievement of beneficial use (maximum utilization) while preserving property interest in water rights. -No legal constraints.	-An organizational structure must be initiated to communicate the various programs to the farmer. -Strategies for implementation must be created, i.e., demonstration farms.
III.A. Provide cost-sharing programs for capital improvements.	-Would allow better on-farm management, reducing quantity of return flows.	-Would encourage investment in quality--improving plant and facilities, such as canal and lateral lining, new irrigation equipment, etc.		
III.B. Make incentive payments for improved water management practices.	-Would encourage improvements in management of land and water for pollution control.	-Would encourage adoption of quality improving methods and techniques, such as irrigation scheduling.		
IV. Provide technical assistance in land/ water management programs.	-Improvement in water quality would depend on level of adoption.	-Would encourage & facilitate installation of needed facilities & adoption of improved practices. -This would be a public investment in improved water quality.	-No legal constraints.	-Refer to Statement V. -Which organizations will be involved?
V. Facilitate sales of the annual allotments or fractions thereof at negotiated prices.	-Depends on use to which water is put.	-Would improve efficiency of water use, moving "surplus" water into higher-value uses.	-Prohibited by the USBR if on a permanent basis and outside district boundaries. -If annual transfers, no legal restrictions aside from the requirement that project users cannot be adversely affected.	-Should improve understanding of significance of water to agricultural production in the Valley.
VI. Sever the water right from the land and allow transfers (sales) of rights.	-Depends on use to which water is put.	-Would cause change in use of water supply moving some water into nonagricultural uses. -While ability to buy a right, as opposed to a one-time allotment, is very attractive to potential buyers, potential sellers in an area with highly variable surface deliveries are less likely to enter the market with rights than with allotments.	-Under Reclamation Law, water rights belong to the BOR until the project is paid off, then assigned to the district. The water rights are for certified lands. -It would be necessary to have legal agreement between the district and the USBR to implement this alternative.	-May serve as a catalyst to further urbanization. It would involve change in water management practices & policies. -Wouldn't be popular among district members. -Conflict among users may emerge due to questions of whether rights should be sold and to whom.

(continued)

TABLE 12 (continued)

Institutional Alternatives	PROBABLE EFFECTS			
	Water Quality	Economic	Legal	Sociological
VI.A. Limit sales to agricultural users.	-Depends on use to which water is put.	-Would cause continuing use of water in agriculture and thus a lower total value-in-use.	-Legally possible within districts provided district rules do not provide the contrary. -No state law restrictions.	-Would encourage continued growth of larger farms at the expense of the smaller farms. -Would make this alternative more acceptable.
VII. Add element of water quality to water right.	-Would maintain water quality within useable limits.	-Would increase cost of water use, to maintain water quality and cause changes in crops irrigated.	-Would only apply to new water rights and changes requested in existing rights. -Would provide right holder administrative course of action.	-Considerations that must be taken into account: ·Monitoring quality standards; ·Enforcement mechanisms; ·Capability of users to comply. -Conflict among users with new rights and those with old rights will ensue.
VIII. Issue regulation for beneficial use.	-Depends on how strict the definition of beneficial use is.		-Would enable state to effectively control waste.	

default on several occasions. There has been disagreement about what water may be used to fulfill the compact, e.g., can drainage waters be used as a portion of the delivery. There is disagreement in Colorado about how Colorado's share should be used.

The Texas Water Plan is such a remote possibility that it does not deserve much consideration at this time. But the master plan calls for a diversion from the Mississippi, some of which would reach Elephant Butte Reservoir. It would probably be very expensive water.

The technology of weather modification is unproven, but increased precipitation in the Rio Grande watershed is a possibility. There could arise some quite difficult problems of rights to such "new" water. If rainfall in Colorado is induced by cloud seeding, is it Colorado's water or Compact water? How will it be shared? Who will bear the costs of weather modification? When such questions arise, the irrelevance of political boundaries to water supply and use is obvious.

Other measures are possible which relate principally to water quality improvement. These are phreatophyte eradication, pumping of high quality ground water, reservoir evaporation suppression and prevention of natural salt inflow.

The U.S. Bureau of Reclamation plans to restore to the Rio Grande a substantial portion of the water now consumed by noncommercial vegetation between the Colorado-New Mexico state lines and Caballo Reservoir. This is to be accomplished by selectively removing about 17,800 acres and thinning about 2,800 acres (1,134 ha) of noncommercial phreatophytes and to control the regrowth on the cleared and thinned areas. As clearing progresses, the plan would also provide for construction of drains as necessary to maintain a lower water table to recover salvaged water and discourage regrowth (USBR, 1971).

The area of infestation in this reach is estimated to be 54,900 acres (22,235 ha). The clearing and thinning of the proposed area is estimated to salvage 1.83 acre-feet per annum per acre or 34,700 acre-feet (4,279 ha-m) per year. Earlier salvage projects, including construction of the Rio Grande conveyance channel at San Marcial, are estimated to have salvaged almost twice this amount of water (New Mexico State Engineer, 1967).

The total cost of the water salvage project has been estimated by the USBR to be $3,568,000, including funds for a 5-year Bureau of Sport Fisheries and Wildlife study of the interrelationship of the vegetation and upland game. Annual operation, maintenance and replacement costs have been estimated to be $165,000 (all costs at January 1972 prices). The benefit-cost ratio has been calculated to be 4.63:1, based on a per-acre-foot value of $44 for irrigation water. The salvaged water would provide an additional 0.22 acre-feet per acre (0.07 ha-m/ha) for irrigators, less losses. As water consumed by phreatophytes is essentially pure water, the salvaged water would be of the highest quality possible.

The plans for phreatophyte eradication have met vigorous opposition from environmental groups who have expressed concern for possible detrimental effects on wildlife. Therefore, notwithstanding the economic benefits to the downstream irrigators, consideration must be given to the overall environmental impact.

High quality ground water is available in the Santa Fe aquifer underlying the Rincon and Mesilla Valleys and in the Huerco Bolson in the El Paso Valley near El Paso. The latter source is used for municipal supply by the city and has not been extensively developed for agricultural use because of limited recharge (estimated to be between 5,600 and 15,000 acre-feet (690 and 1,850 ha-m) per year)). The Santa Fe aquifer is now beginning to find use as a source of agricultural water.

Water in the Santa Fe aquifer generally has a conductance of 300 to 1,000 mmho/cm compared to 500 to 5,000 in the alluvial aquifer, and is therefore to be preferred for irrigation. The Elephant Butte Irrigation District has constructed five wells into the aquifer, these wells ranging from 420 to 1,200 feet (128 to 366 m) deep. The deepest well is 12 inches in diameter and produces 4,310 gallons per minute (27 l/sec) of high quality water. More wells are under construction and planned. All of the wells will discharge into the EBID's distribution system.

This possibility for increasing the volume of available, good quality water must be attractive to many farmers and water managers. But there should be concern about the longer term impacts of pumping from the aquifers. Will such use eliminate ground water reserves upon which irrigators draw in water-short years?

The source and rate of recharge of high quality water to the Santa Fe aquifer has not been accurately defined. Removal of water from the aquifer in excess of this rate would constitute mining of this resource. The alluvial aquifer immediately overlies the Santa Fe aquifer, and hence lowering of the piezometric pressure in the underlying aquifer can be expected to induce an infiltration of lower quality water from above. However, it is expected that this source can provide great benefits to the district if it is used to supplement water in the river. The marginal increment will be valuable, especially in water-short years.

The ground water resources of the study area are currently under study by the U.S. Geological Survey in New Mexico and by the Texas Water Development Board in Texas. The results of their respective studies should give considerable insight into the desirable extent of exploitation.

The Elephant Butte Reservoir has one of the highest rates of evaporation of any in the United States. Evaporation from a Class A pan averages 118 inches annually, or approximately ten times the precipitation. Considerable research has been carried out at Elephant Butte into means of evaporation suppression. As with transpiration by phreatophytes, evaporation constitutes the removal of pure water. The salvage of up to several hundred acre-feet of this water per year would have a major water quality effect downstream and would be of major economic benefit to irrigators.

Although research on evaporation suppression appears to have slackened in recent years, it still is an area in which potentially large water quality improvements are possible. Suppression of a large percentage of the evaporation from Elephant Butte and Caballo Reservoirs would represent the salvage of more high quality water than any other measure.

Galisteo Creek, the Rio Puerco and the Rio Salado discharge into the Rio Grande a salt concentration approximately three times that of the receiving waters. These three streams alone load the river with 105,000 tons (115,500 metric tons) per year on average, having an average discharge weighted concentration of 1,150 mg/l. Their contribution to the flow in the river averages 66,000 acre-feet (8,138 ha-m) per year. Their effect is to raise the concentration of the Rio Grande at San Marcial to 460 mg/l from the 440 mg/l it would be without them. (All figures are based on the period of available records, 1966 to 1972.) The contribution from other ungauged streams is probably quite small, as the catchments of these three streams, together with the Jamez River (which contributes better quality water), include most of the land area of the Rio Grande Basin from Otowi Bridge to San Marcial.

The inflow of salt from these streams into the Rio Grande could be reduced by retention and evaporation or by desalination. Both methods would be expensive and difficult to justify. The quality of the inflowing water is adequate for the growing of many crops and is in fact better than the average quality received by irrigators in Hudspeth County. The overall effect on TDS in the river is very small and the removal of this water from the system would ultimately deprive the Hudspeth County irrigators of that quantity.

Improvement of the Water Delivery Subsystem

The Rio Grande Project is an old project, dating back to the period 1915-1925. Many of the irrigation ditches now in use were built even earlier. Some ditches on the project go back to the late 1600's. When the project was formulated, many of these old ditches were incorporated into the system as it is today. Furthermore, the Rio Grande was redirected and rechanneled in the 1930's. Thus, many irrigation facilities that were placed by virtue of a former position on the Rio Grande have now no real reason to be in their present location (Cunningham, 1971).

In view of this, the Elephant Butte Irrigation District plans to modernize its system to take advantage of more recent technological developments, reexamining and reengineering the distribution facilities to minimize and eliminate as many redundant facilities as possible. A complete reevaluation of the distribution system (known as the Archer Plan) would consider the improvements discussed below.

As reregulating reservoir would be constructed somewhere on the project downstream from the last diversion in the Mesilla Valley. The primary canals would remain in their same general locations. From these primary canals, laterals would extend at about right angles from each side of the canal to the river or hill line. These laterals would be spaced at about one mile intervals and would serve from about 600 to 1,800 acres (243 to 729 ha) each. It is contemplated that these laterals would consist of pipe conduit. The main canals would be equipped with a system of on-site automatic checks and a series of wasteways that would discharge to the river and ultimately to the reregulating reservoir. These automatically controlled checks would maintain a constant head over the pipe conduits, thus permitting a non-varying irrigation head (which would allow the delivery of a constant flow rate to each farmer). This system would operate within the capacity limits of the main canal. Releases from storage reservoirs would be of proper amounts to satisfy all systems and irrigation water would be reregulated for downstream use at the reregulating reservoir.

A modification to this plan may now be suggested which incorporates water quality features. In addition to placing the laterals in pipe conduit, the main canal could be lined to form an aqueduct from Caballo Dam to El Paso and beyond to the lower end of the Rio Grande Project. This would include carrying the flow in the aqueduct through Selden Canyon and the pass at El Paso so that at no time would the water flow in the river channel. The aqueduct would carry the water supply for the Elephant Butte Irrigation District, the City of El Paso, the El Paso County Improvement District No. 1, and that required to fulfill the treaty obligations to Mexico. The water would be carried in inverted siphons under the large uncontrolled arroyos to prevent contamination.

The use of wasteways to the river and a reregulating reservoir within the EBID would not be necessary as the large capacity of the lined canal carrying the total water supply would provide a large degree of buffering (regulation) when used in conjunction with automatic water level controllers. A reregulating reservoir would be necessary toward the lower end of the El Paso CWID No. 1 to regulate inevitable operating wastes for use lower in the system.

In addition to the advantages envisaged by the Archer Plan, the provision of a lined aqueduct through the length of the project would offer a number of water quality advantages.

The substantially reduced seepage from the canal and laterals would reduce the possibility of salt pickup. Perhaps more significantly, demand irrigation scheduling by farmers and accurage measurement of deliveries would allow better on-farm management and a closer control of deep percolation to more closely approximate the leaching requirement. The combination of reduced seepage (estimated to be at least 20 percent of the water diverted to the canals) and deep percolation would lower the water table, further reducing evaporation from swamps and bogs and transpiration by phreatophytes and preventing salt damage to agricultural lands where the water table is close to the surface.

Concrete lining and related improvements to the existing distribution system from Leasburg Dam to near the American Dam have been estimated by the USBR (1956) to salvage about 98,400 acre-feet (12,133 ha-m) annually for project use in addition to providing to Mexico 11,800 acre-feet (1,455 ha-m) annually to meet treaty obligations.

Reduction in the project water delivery losses would decrease the requirements for releases from project storage and increase the duration of retention. This would result in increased evaporation from storage, the amount depending on storage level, with a resulting increase in total dissolved solids in the reservoir releases. This increase would be less than currently occurs on passing through the project. The city of El Paso, Mexico, and all elements of the Rio Grande Project would receive water of equal quality, being the quality of water stored in Caballo Reservoir. An additional benefit would be the reduction or elimination of the need to pump ground water.

The cost of system rehabilitation within the Elephant Butte Irrigation District has been tentatively estimated by the district manager as $100 million. The rehabilitation would be carried out for its operational advantages rather than water quality considerations. The USBR estimated in 1956 that it would cost $17,190,000 to construct a lined conveyance channel and related facilities from Leasburg Dam to near the American Dam. An aqueduct from Caballo Dam to El Paso carrying the water requirements of the Rincon and El Paso Valleys, the City of El Paso and Mexico, in addition to those of the Mesilla Valley, would require more than twice the capacity and would be about 75 percent longer. The cost (present prices) could be as much as $100 million for this aqueduct.

The expected benefits in continuing the aqueduct below El Paso would need to be considered separately. At this point, the primary objective of delivering high quality water to the El Paso Irrigation District, to the expanding city of El Paso and to Mexico would have been achieved. Some return flows and drain waters are reused in the lower part of the valley and the benefit these lands would receive from the delivery of the high quality water would have to be weighed against the cost of continuing the aqueduct to the end of the project. The operational advantages of rehabilitating the irrigation district would probably play a large part in this decision.

Planners for the city of El Paso are contemplating the necessity in the future to construct a large diameter pipeline from Caballo Reservoir to the city for domestic water supply. This would depend of course on acquisition of additional water rights. The city currently contracts with the USBR for the delivery of a small quantity of project water and the conveyance of water from the Canutilla well field in the river to the treatment plant. As the city expands, additional water will be required. The ability of ground water supplies to meet this demand is limited, and most of the distant future additional water demands will need to be supplied by the Rio Grande. The cost of treating this additional quantity of water could justify the cost of building the pipeline from Caballo. This water could alternatively be carried in the aqueduct herein proposed, and the cost applied to its construction, which would drastically reduce the costs to the irrigation districts. However, the needs of the city may not correspond temporally with those of the irrigation district. Should the aqueduct be extended to the end of the project, some of the salvaged water might be sold to the Hudspeth District to further offset costs.

With construction of a lined aqueduct to carry the irrigation water supply through the length of the Rio Grande Project, drain returns would be expected to be lower than at present. Water available to the Hudspeth District from this source would be reduced. Operating waste water would still be available, although this could be drastically reduced if the El Paso District were to build a reregulating reservoir in the mid-part of its district and use the collected operating waste for supplying the lower part. Alternatively, should sufficient water be available, the Rio Grande Project may find it more economical to sell all waste water to the Hudspeth District rather than to construct the reregulating reservoir. If 5 percent of the water allocated to the Rio Grande Project farm lands were wasted, this would provide 1.33 acre-feet per acre (.4 ha-m/ha) to the 18,000 acres (4,290 ha) of the Hudspeth District. More importantly, this water would be of equal quality to that being delivered to the upper Valleys, having an average TDS of about 500 mg/l compared to the present quality of 1,500 mg/l.

The operating waste water from the Rio Grande Project could possibly be conveyed onto the higher ground beyond Fabens, rather than along the flood plain, and stored in an arroyo dammed for the purpose of providing adequate capacity to receive such water. The land in the El Paso District below Fabens would be served by Tornillo Canal, with any water wasted from this canal passing into the existing regulating reservoir at the county line. This reservoir should be deepened to provide the additional capacity necessary to store any arroyo inflow coming down the river. Although no estimate is available of the amount of arroyo inflow available to the district, the fact that an average of 76,000 acre-feet (9,371 ha-m) of water per year (not including 1942 when Elephant Butte Reservoir spilled) passes Fort Quitman indicates that more water could be made available to the Hudspeth District if storage facilities existed in which to conserve the water. Some of the tributary arroyos could possibly be dammed to provide this storage and the regulating reservoir at the county line also kept as empty as possible to provide maximum storage potential.

With high quality water from the upper districts and arroyo inflow available to the Hudspeth District, it may be justifiable to rehabilitate many of the district's facilities. Prevention of seepage losses would allow water savings, and better water control.would allow better on-farm water management. Potential would exist for reclamation or improvement of salt affected lands.

The possibilities outlined above are by necessity cursory in nature and dependent on the actions taken in the upper districts. Notwithstanding, the solutions to the problems faced by the Hudspeth District, as reflected by the acreage out of production and the lower per acre returns compared to the other districts, may not be able to be prolonged until the other districts act. These problems and their solutions require detailed study. However, they relate more to the viability of the Hudspeth District as an irrigated agricultural area than to water quality per se.

Improvement of the On-Farm Subsystem

There is a paucity of data for most irrigation systems in the Western United States regarding on-farm evaluation of irrigation practices. The lands of the subject area are no exception. Much can be accomplished by analyzing existing irrigation methods and practices on a sufficient number of farm fields so that proper advice can be given to farmers regarding modifications to existing irrigation practices that would result in both water quality benefits and increased crop production.

Historical canal diversions show the typical trait of large water deliveries during the early season; however, the regulation provided by Elephant Butte Reservoir is more than sufficient to allow water deliveries to be made more according to crop water requirements. For example, the American Canal diverts to El Paso Valley an average (1939-73) of 30,000 acre-feet (3,699 ha-m) in March and 32,000 acre-feet (3,946 ha-m) in April, after which diversions are reduced in May to 27,000 acre-feet (3,329 ha-m) (see Table 13). The April diversion alone is 75 percent of the average diversion for July and August when consumptive use could be expected to be at a peak. During the three-month period, March, April and May, 33 percent of irrigation diversions occur, while only about 20 percent of crop water requirements can be attributed to this same time period. The large spring diversions not only satisfy leaching requirements, but may also contribute to soil salinization as a result of capillary rise from high ground water levels (waterlogging).

Traditionally, surface irrigation methods result in too much water being applied during seedling and plant emergence growth stages. This is the combined result of early season irrigation practices being similar to later irrigations when larger water applications are necessary, as well as inherent physical limitations in surface irrigation methods. However, much could be done to "tune up" such irrigation methods to allow higher early season irrigation application efficiencies. A cognizance of desirable early season improvements would undoubtedly have carryover effects into later irrigations, thereby enhancing water use efficiency throughout each irrigation season.

TABLE 13. AVERAGE DIVERSIONS TO AMERICAN CANAL AT EL PASO, TEXAS, 1939-1970.

Month	Diversion (acre-feet)	Diversion (hectare-meter)
January	1,500	185
February	4,569	563
March	30,226	3,727
April	31,545	3,890
May	27,035	3,333
June	35,982	4,437
July	43,514	5,365
August	42,656	5,259
September	28,047	3,457
October	11,600	1,430
November	6,905	851
December	6,825	842
Yearly TOTAL	270,394	33,340

SOURCE: International Boundary and Water Commission.

Field measurements are needed on farm fields throughout the study area in order to establish the quality, quantity and timing of farm irrigation deliveries (both surface canal deliveries and ground water pumping), the flow characteristics of the irrigation method being employed (which is almost entirely by surface methods), consumptive use by crops, tailwater runoff, leaching requirements, and the quality of deep percolation losses. An important consideration in the field data collection and analysis, in terms of on-farm water management and optimizing water resources utilization in this study area, is the utilization by farmers of the more saline ground water flows during drought years. For each field from which such data are collected, recommendations can be made regarding modified irrigation practices that would more beneficially utilize water supplies and fertilizer. In addition, the use of these data in a hydrologic evaluation of each valley, as well as the hydrologic interaction between valleys, will allow recommendations to be made for the entire study area. Also, this field data will show constraints being faced by irrigators in achieving higher irrigation application efficiencies.

The results of the field studies should yield recommendations regarding a variety of physical improvements which could be undertaken to eliminate some, or all, of the constraints faced by the water users. These recommended physical improvements can consist of simple modifications to the existing irrigation method (e.g., concrete head ditches, employing different sizes of siphon tubes, flow measurement structure(s), gated pipes, automated concrete head ditches, etc.); conversion to new irrigation methods (e.g., converting from furrow or border irrigation to sprinkler or trickle irrigation); or could involve physical improvements in the water delivery subsystem, in particular the lateral(s) (e.g., lining the lateral, placing the irrigation water supply in a pipeline, constructing water measurement structures, improved water control structures, etc.). For a discussion of the merits of sprinkler and trickle irrigation, see Appendix B, at the conclusion of this report.

Improvements like these envisioned are not, of course, costless. Considerable modification in some systems would be necessary to achieve efficiencies possible with improved systems. Some systems would have to be abandoned in favor of new ones.

Some special inducements to allow and facilitate changes in farm subsystems may be necessary. Low interest loans, perhaps made through commercial channels with governmental guarantees, would permit some farmers to modify or replace outmoded systems. Cost-sharing arrangements, perhaps through the Agricultural Conservation Program, might be effective in inducing changes. Special educational efforts, to demonstrate the effectiveness of improved subsystems, would facilitate the development of more efficient irrigation technology on farms. Ultimately, the feasibility of improved facilities for applying water would have to be shown. But with the emphasis on improved water quality, the feasibility of improved systems may have been enhanced. If farmers must internalize pollution costs, they may be quick to employ pollution-reducing technology.

Irrigation Scheduling

Irrigation scheduling programs have been developed for many areas. The USBR has developed irrigation scheduling services for some of its projects, developed with a fivefold objective to:

a. increase crop yields and quality;

b. reduce fertilizer losses;

c. reduce the amount of unnecessary water and labor inputs to farming;

d. reduce drainage problems; and

e. improve the quality of return flows.

From the individual farm operator's point of view, the objectives may be summarized as: applying the optimum amounts of water at the optimum time intervals to obtain the maximum economic returns.

Long before the advent of digital computers, climatological monitors, or instantaneous communication systems, successful irrigation farmers were scheduling irrigations based on, for example, the appearance of the crop or the feel of the soil. However, the fallibility of experience and judgment has been demonstrated throughout the world as overapplication of water has led to yield reductions due to fertilizer leaching, poor soil aeration, and plant diseases. In addition, such inefficient irrigation practices have created regional water quality problems, mosquito nuisances, public health problems, and local property damage due to waterlogging of soils and seepage of water into basements of homes and businesses.

The relative ease with which irrigation can be programmed for digital computers has allowed irrigated scheduling service to be provided to a large number of irrigators by a single facility. Modern districtwide irrigation scheduling programs consist of six primary steps (Figure 14).

First, an inventory of the soil and crop characteristics for each field is made to gain an understanding of the essential requirements for efficient irrigation. Then, a calculation of the water needs of the growing crops is made, specifically, at what rates are the crops and soil surfaces utilizing water from the soil moisture reservoir. Such estimates are generally based on well tested empirical techniques, rather than actual measurements, because of convenience and the established reliability of the computational procedures. The next aspect of irrigation scheduling is to determine the availability of moisture in the root zone for meeting crop needs between irrigations. This step is accomplished by initially sampling the soil profile to measure the available moisture and update the consumptive use estimates. Upon determining the amount of soil moisture available, the interval between irrigations is projected. In addition, by knowing the soil and irrigation system characteristics, the amount of water to be applied (as well as the means to accomplish the suggested application) can be determined. Finally, the results of the previous steps must be delivered to the irrigator in order

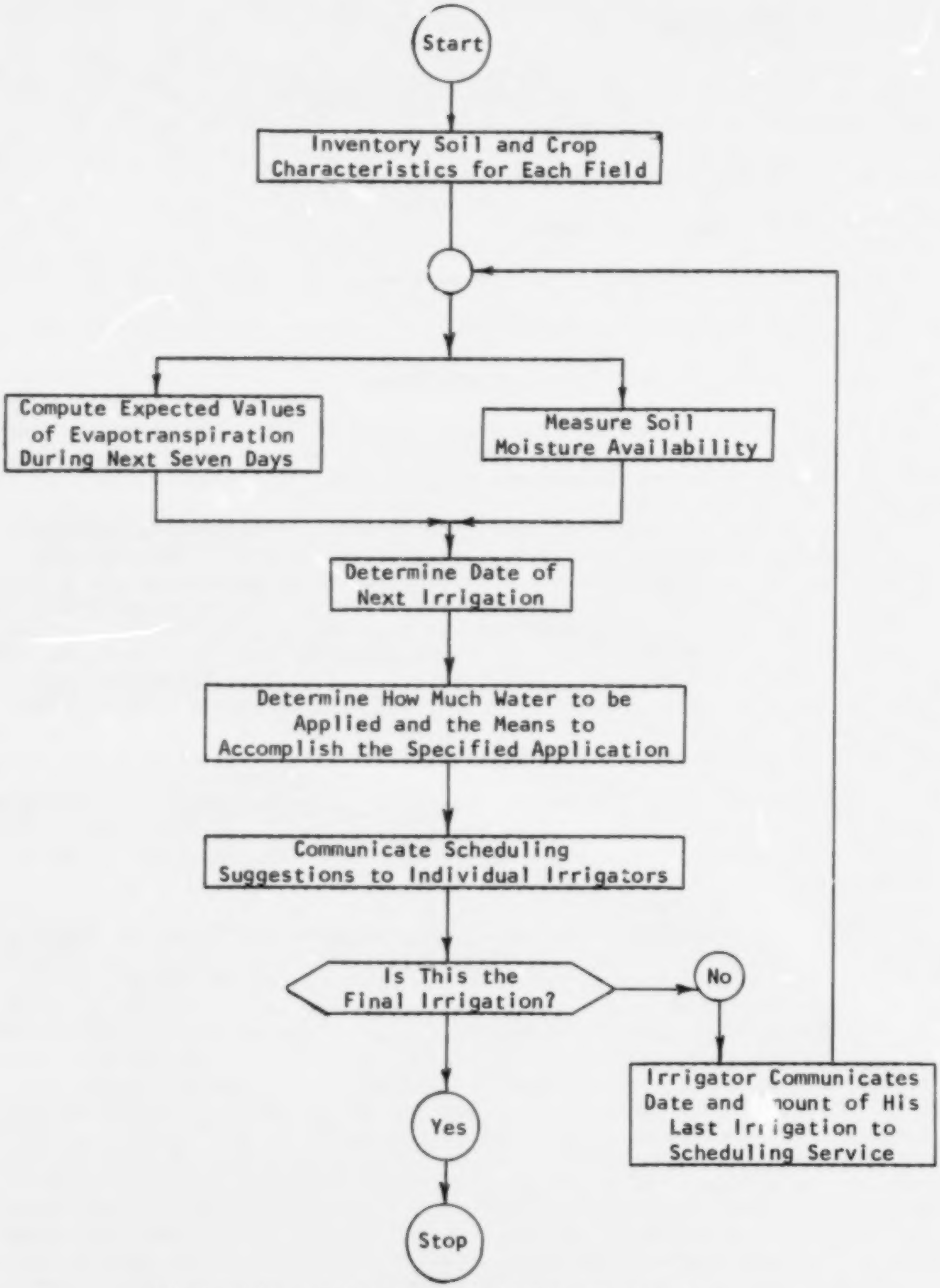

Start
Inventory Soil and Crop Characteristics for Each Field
Compute Expected Values of Evapotranspiration During Next Seven Days
Measure Soil Moisture Availability
Determine Date of Next Irrigation
Determine How Much Water to be Applied and the Means to Accomplish the Specified Application
Communicate Scheduling Suggestions to Individual Irrigators
Is This the Final Irrigation?
No
Irrigator Communicates Date and Amount of His Last Irrigation to Scheduling Service
Yes
Stop

Figure 14. Irrigation scheduling components.

to implement the suggestions. Also, proper implementation is highly dependent upon flow measurements being available to the farmer so that he knows "what he is managing." This program is subsequently repeated throughout an irrigation season.

An irrigation scheduling service offers the potential to improve water quantity and quality, while at the same time enhancing returns to the farmer. The cost varies according to the extent of service offered, but is usually in the range of $1.50 to $5.00 per acre ($3.70 to $12.35/ha).

The U.S. Bureau of Reclamation implemented an irrigation scheduling service in El Paso Valley during the early 1970's, but this program was unsuccessful and was terminated after the 1974 irrigation season. The lack of flow measurement structures, along with a lack of necessary field data for "tuning up" the irrigation system, can be credited with the demise of this program in the El Paso area.

Return Flow Subsystem

In order to increase agricultural productivity on some lands in El Paso Valley, tile drainage would probably be desirable. Field data is required in order to establish the suitability of tile drainage as a measure for increasing crop production, as well as improving the quality of irrigation return flows. Tile drainage should only be undertaken in conjunction with improved on-farm water management practices, which in turn benefit from physical improvements of the laterals delivering water to the farms.

Desalination of Return Flows

Although desalination would not appear to be necessary at the present time, or in the immediate future, this technology may become important in future decades as a result of increasing urban demands in El Paso Valley. The use of tile drainage effluent as the inflow to a desalination plant would be feasible if sufficient acreage is underlain by tile drainage. Also, at that time, pump drainage may be desirable as a means of both reclaiming agricultural lands and providing the saline water supply to a desalination plant.

A Discharge Permit System

It is the present intent and effort of the Environmental Protection Agency and cooperating state agencies to control discharges of effluents (return flows) from agricultural lands. The effort has not been successful to this point because of the resistance encountered from agricultural users of water. Believing in the inappropriateness of the NPDES, they have brought suit against EPA in several states and have effectively blocked an imposition of this control program on irrigated agriculture.

A discharge permit system does offer the potential for limitation of effluent discharges and the control of quality of water in receiving streams. But, a significant first problem in the implementation of such a system is recognition, location and continual monitoring of return flows. These flows are quite diverse and often are largely hidden. Unless collected by drainage ditches, terraces and other devices, the quantities cannot be effectively measured and the quality of flows cannot be ascertained. The monitoring technique now employed is that of sampling the waters of receiving streams and evaluating the quality of the samples. This technique will not be sufficient for issuance of permits and monitoring of discharges of permit holders, unless groups or organizations of water users, e.g., irrigation districts, are the recipients of the permits. This would make enforcement possible and greatly reduce the costs of a quality monitoring program. But, it would place the burden of enforcement on the organization of users. The irrigation district management would be required to monitor water use by individual farmer-members. We should not expect that irrigation or drainage districts would welcome this responsibility. The organizations might be directed by members to function as permit holders and policemen, if the members saw no alternative to the permit system.

Whether irrigated agriculture could survive with water quality controlled by a discharge permit system will depend upon the stream standards adopted in areas where irrigated agriculture is the dominant user of water. Water quality degradation is an inevitable consequence of irrigation. Even when water is not efficiently used, the concentrating effect will cause mineral concentrations in streams to rise. Decisions must be made about stream standards that are consistent with water uses, water values, and demands for water quality before we expect to employ a permit system in the control of quality of return flows from agriculture.

Taxes and Subsidies

The difficult problem of monitoring return flows from individual tracts or parcels of land will prove troublesome also in the implementation of one kind of pollution tax, i.e., a tax on effluent discharges. The kind and amount of effluent is the basis for the tax. The tax is levied to cause the internalization of the cost associated with treatment of the effluent.

A user tax might also be employed, which increases the price (conveyance cost) of water to reflect the cost of pollution. It would not require the monitoring of return flows. It is a tax on the water diverted and is used to assess everyone, quite equally, for the damage done to water (i.e., to succeeding users) as it is used in agriculture.

The basic problem of implementation is simply that the effluent or user tax increases the price of water. And, the profit maximizing producer resists all increases in prices of productive inputs. Where he can have a voice in price increases, he protests--loudly. The user tax will, however, increase the price of water, cause more efficient use of this scarce resource and generate revenues which can be used to promote improved water management, or share costs of new distribution facilities, or treat the effluent (desalination of return flows in the Rio Grande).

The subsidy of recommended rehabilitation of distributional facilities, or of improved irrigation systems, or of new knowledge about using irrigation water is usually acceptable to managers and users of water. Taxpayers may not always endorse such assistance with good facilities and good practices, but some are inclined to go along with it, thinking that an improvement of water quality is worth a small share of the cost of improvement. We have some tradition of cost-sharing by government, to promote the adoption of soil conserving methods and practices. The use of subsidies to provide incentives for approved water management methods and practices should not, therefore, be difficult to "sell" to the general public and to affected, water-using farmers.

Technical Assistance in Land/Water Management Programs

Provision of technical assistance for rehabilitation of distributional facilitites and improvement of land/water management methods and practices should be quite acceptable among irrigation farmers. Such a program will have as its basis the many years of work of the Soil Conservation Service. This organization will undoubtedly be at the forefront in the extension of technical assistance to water users.

Coupled with subsidies, i.e., cost-sharing programs, this program of assistance should provide for implementation of several of the measures recommended by researchers and techniques for improvement of water use in agriculture. These were previously identified as canal and ditch lining, flow measuring devices, improved irrigation systems and methods, irrigation scheduling, improved drainage, etc. Downstream users of water, in particular, and the public, in general, will benefit from these programs, in that they will positively affect water quality. Farmers (irrigation district members) will benefit in the provision of technical services at little or no cost and in the installation of improved facilities at a fraction of total cost. In some cases the subsidy will be in the form of low-cost loans; in others it will include cost-sharing. The decision about the subsidy is a political one, to be made by the Congress.

Sales of Allotments or Rights

Sales of all or portions of allotments is a well-established practice in the Elephant Butte District. They can probably be expanded in the El Paso District by only a little more experience with the practice. There is little motive for transfers of allotments in the Hudspeth District.

Where transfers of water are regularly made, there is recognition of the values of water in alternative uses and thus the opportunity costs associated with its use. There is little or no fear of loss of the annual allotment, so farmers rationally exchange and sell allotments.

It will be more difficult to develop a market for the water rights. In Elephant Butte, where rights are held by the irrigation district, the rights would have to be returned to the district members, then severed from the land in order to make them negotiable. With negotiability, they could be sold to anyone willing to buy, so that some rights (water) would leave agriculture. The values of water would be higher in the nonagricultural uses; returns to the limited resource would be greater. But there would be great resistance among right holders in the project area to movement of water out of agriculture. The Bureau of Reclamation would not be inclined to favor such transfers out of project areas. So, efforts to create a market for water rights are probably not going to be successful. If El Paso continues to grow and develop industrially, there may be efforts to buy water rights for urban uses. The potential should not be ignored.

Modification of the Water Right

There are numerous ways in which the water rights system in the Western United States, and particularly the case study states of New Mexico and Texas, can be improved. However, two specific changes have been suggested that will increase the ability of the two states' water agencies to attack the problem of controlling degraded return flows. These two suggestions are: a) to add the element of water quality, specifically, to all new water rights and as a condition to transfers or other changes in existing water rights; and b) to promulgate regulations which set out standards and criteria for beneficial use.

The first change is not foreign to Texas or New Mexico on an ad hoc basis. As previously stated, in Texas a condition to granting a water right is that if return flows exceed water quality standards, diversions under the right can be curtailed. Also, in New Mexico there are several instances (in the Pecos River Valley) where water quality of downstream users has been protected by incorporating the requirement of useable return flows in upstream water rights. Adding water quality can be within general reference to the restrictions against discharging return flows of unreasonable quality under use and technology conditions, or where the need exists and conditions prevail numerical standards can be placed in the water right. It is well accepted that this recommendation cannot be applied to existing water rights as a new feature. But, where case law or existing statutory provisions recognize water quality specifically as an element of a water right, then specification of the element could take place.

The second legal modification is to define beneficial use more concretely by setting up standards and criteria. This requires no statutory modification in either state for surface water and can be applied to ground water in New Mexico under this administrative structure. The standards and criteria will serve as the guidelines for water users and should be established for both conveyance and application efficiencies.

The two modifications, together, will enable the water quantity and water quality agencies to control a problem determined to exist through concerted effort, and not place the burden strictly upon the "effluent" controller where a significant impact can be made by the "influent" controller. Flexibility must be maintained in the administration of the law so that intensive regulation would only occur in areas where a significant problem exists. The reason for this is to minimize the cost of water use by requiring higher standards of conveyance and use only in problem areas of the state.

FIELD ASSESSMENT OF POTENTIAL SOLUTIONS

Upon completion of the evaluation of alternative solutions by the research team, attention was directed to an assessment of potential solutions by persons in the "field," i.e., federal and state agency personnel concerned with administration of water laws in the study areas, managers of irrigation districts, and farmers who are users of irrigation water and persons most affected by water quality laws and regulations.

The "Summary of Technological and Institutional Alternatives," Table 14 was used as a discussion outline in contacts with persons in the study areas. The "Rationale for Discussions..." outlined in Table 14 was used to introduce the content of our discussions. This procedure allowed us to approach all the persons interviewed in the same way, i.e., with the same objectives, same explanation, and the same questions. It is an approach essential to the reduction of bias and to acquisition of information which can be used in comparing responses to alternative solutions.

TABLE 14. RATIONALE FOR DISCUSSIONS OF WATER QUALITY PROBLEMS WITH WATER USE ADMINISTRATORS, DISTRIBUTION SYSTEM MANAGERS AND WATER USERS

I. *We have asked you to meet with us as participants in a research project which may be important to the use of water in agriculture.*

  a. *We are inquiring about the quality of water used in irrigation and returned to the source.*
  b. *We are considering the alternative means and mechanisms for maintaining that quality.*
  c. *We are asking water users to help us evaluate those means and mechanisms that may be employed to maintain quality.*

II. *We are all aware of the growing public interest in water quality. Evidence of this interest is the Water Quality Control Act of 1972, which expresses our intent to clean up the Nation's waters.*

  a. *We are directed to establish quality standards, identify pollution sources, measure and specify the pollutants, and take action to control waste water discharges.*
  b. *Various governmental agencies, chiefly the EPA, were given the responsibility for implementing the Act.*

III. *We are also aware that a use of water which is important to us, i.e., irrigation of crops, causes degradation of stream quality as silty or salty return flows find their way back to the source.*

  a. *Some of this kind of pollution is inevitable--it is a natural consequence of use of water for irrigation.*
  b. *But some return flows are unnecessarily silt laden or saline. They are a consequence of improper management of water in diversion, distribution and/or application of water to land.*
  c. *We know that we must take action to remedy these pollution problems.*

But what should we do?

(continued)

TABLE 14, continued

IV. *The EPA, acting at the instruction of Congress and without understanding irrigated agriculture, tried to implement a control program--a discharge permit system.*

   a. *This system was not appropriate to agriculture and it is not working.*
   b. *They now seem ready to consider something else--a different approach to maintenance of quality of streams where water is diverted for irrigation.*
   c. *They have commissioned us to find and to evaluate alternatives to the discharge permit system.*
   d. *We have committed ourselves to a search for workable alternatives and we seek the involvement of water users in this search. For an implementable policy or program for pollution control must be acceptable to those who will be affected.*

V. *Now, the Rio Grande Valley has been identified as an irrigated area with a problem--a problem of salinity created by concentration of salts in return flows. We have reviewed the evidence and find that this problem does, in fact, exist. So we have started our search for alternative solutions--solutions that will alleviate or eliminate the problem and that can be implemented.*

VI. *We began with the understanding that institutions (e.g., taxes, subsidies, permits, rights, pricing policies, etc.) are as important to pollution control as technologies (e.g., canal lining, new irrigation systems, treatment plants, etc.).*

   a. *We have sought those institutions, technologies, or combinations of institutions and technologies that are acceptable, or least objectionable, to water users in agriculture.*
   b. *We have screened our lists of alternatives via consultation with water lawyers, water agency personnel, district managers, et al.*
   c. *We now seek your evaluation of these alternative, pollution controlling technologies and institutions. And, if we've overlooked some, we hope you will add them to our list. Will you look at them with us?*

Response to these solutions depended to a great extent on who was doing the evaluating, i.e., who was being interviewed. State and federal agency personnel, who had responsibilities for administering laws governing rights to and distribution and use of water, were inclined to favor measures that fit within the framework of existing laws, rules and regulations. Conscious as they were of problems of implementation, they resisted alternatives that required new laws, rule changes, etc., which would affect administration. Managers of distribution systems were very conscious of their responsibilities in the transport and delivery of water to users. They favored proposals to improve distribution systems and to provide financial assistance with capital improvements. They resisted alternatives that suggested controls on allotments, diversions, use and return of effluent to receiving waters. But, they recognized the possibility that such measures might be necessary and they reluctantly agreed that the administration of control programs should be at local levels, with some enforcement responsibilities in their office.

Water users, the members of the irrigation districts and irrigation farmers quite logically favored the alternatives that were directed to improved management of water on farms. They did not quickly admit that inefficiencies in water uses were a problem, except on the farms of poor managers, but they saw the need for improved scheduling of water applications, improved transport of water on farms, and in some instances, new or improved systems of application. They, of course, approved of provision of technical assistance and of cost-sharing and incentive payments. Some maintained that added investments in technology are impossible without some subsidy by the public.

In Table 15, there is a summary of responses of agency personnel, district managers and water users to the proposed technological and institutional solutions.

SUMMARY OF RESULTS

It was previously noted that the participants in the assessment/evaluation process quite logically responded to the alternative solutions from their perspectives. They tended to view the problem and the proposed solutions in terms of the existing institutional framework, the costs and benefits associated with change, the impacts on established practices and methods, and the probable effects on social relationships. Knowing how people looked at the return flow problem and how they responded to alternative technological and institutional alternatives allows us now to recommend solutions, singly and in combination, that will be implementable. The extent of the impact on the problem is not yet determined, for the water quality goals (standards) have not been established and the relative effects of solutions have been only approximately, if not inexactly, determined. But, at this point we do have good indications of what people do not like, what they think will work, what they will cooperate with, etc. And, we have involved affected persons in a problem-solving process that has made them aware of the problem, understanding of its complexities, appreciative of the need for solutions, and aware of potential courses of action that will be problem-solving.

Evaluation of the Assessment Procedure

The assessment procedure was well conceived but it suffered from insufficient participation within all groups. The federal and state agency people showed a reluctance to consider alternatives which were new or unfamiliar to them. They were more comfortable with existing law, associated rules and regulations and established administrative procedures. They were even reluctant to think about amendments or changes in the law. Irrigation district managers were more flexible in their attitudes toward change, but they were

TABLE 15. SUMMARY OF RESPONSES OF AGENCY PERSONNEL, DISTRICT MANAGERS AND WATER USERS TO TECHNOLOGICAL AND INSTITUTIONAL ALTERNATIVES

Technological Alternatives	Agency Personnel	District Managers	Farmers--Water Users
I. Increase flow of the river; expand volume of water.	No responses.	An increase in the available supply of water would of course be beneficial to agriculture. Depending on the source there might arise a question of whose water it is, i.e., how it should be shared.	Any addition to the quantity of water would be welcomed. It would be especially useful to farmers in Hudspeth County, because it would dilute existing water of poor quality.
I.A. Supplement river flow via pumped water.	~~No responses.~~	Pumped water is relatively costly; it would not add significantly to total volume; it is used more efficiently as supplemental water in years of small allotments.	Wells are more effectively used to supplement reservoir water during water-short years. Some wells do not yield good quality water. Some farmers could trade well water for Elephant Butte water.
I.B. Induce precipitation and runoff via weather modification.	No responses.	Technology not yet developed; a costly, risky venture; can't be seriously considered.	Seems like a remote possibility. Whose water would it be? The watersheds are in Colorado and Northern New Mexico.
I.C. Eradicate phreatophytes above Caballo Reservoir.	No responses.	An alternative worthy of pursuit; eradication now blocked by environmentalists; probably will be done eventually.	This is a feasible alternative solution. Phreatophytes are not native vegetation and are heavy water users.
I.D. Suppress evaporation from the reservoirs.	No responses.	Costs of evaporation suppression are presently very high. The current technology is not effective on large reservoirs. Might be a possibility in the future.	Presently, too costly. The techniques of suppression must be developed.

(continued)

TABLE 15 (continued)

Technological Alternatives	Agency Personnel	District Managers	Farmers--Water Users
II. Impound flows of highly saline tributaries.	No responses.	This is not an acceptable alternative. There is now more concern for quantity than for quality of water.	Farmers are too concerned about quantity to be willing to give up flows from any tributaries.
III. Provide aqueduct from Caballo to El Paso and possibly beyond.	No responses.	Would require a separate accounting system for the Elephant Butte and El Paso districts. The good working relationship between the districts would be severed.	Farmers in El Paso district would be beneficiaries and would be willing to share costs of it. But it would be a costly venture and would require public investment.
IV. Improve distribution systems in irrigation districts.	No responses.	An acceptable alternative and one now being implemented by both districts as rapidly as possible. Limitation on implementation is financial.	Within the limits of their financial capability, irrigation district members are investing in improvements in distribution facilities.
IV.A. Line canals and put laterals in concrete pipe.	No responses.	Lining canals will reduce seepage losses. Putting laterals in concrete pipe will allow pressurization of system. This would eliminate return flows attributing to seepage.	A project costing more than $1 million is proposed for Elephant Butte. El Paso district is presently spending more than $400,000.
IV.B. Install flow measuring devices.	No responses.	Would positively affect delivery and application of water on lands in the districts.	Would not be worth the cost. Water allotments are so small that farmers are careful about applications.
IV.C. Modify irrigation practices.	In a policy statement, the Water Quality Commission, New Mexico, declared that where a land use does have a significant impact on water, the Commission would adopt alternative engineering, land use management and regulatory approaches to this type of water pollution.	Modification of methods and practices would not have a major effect on water quality. Evaporation and wind are limiting factors in sprinkler irrigation. Limited use (orchards, vineyards, etc.) is a problem with trickle irrigation.	Sprinkle and trickle irrigation won't work on row crops. Furrow irrigation is the best for many crops in the Valley. Unskilled and careless labor is a problem in water application.

(continued)

TABLE 15 (continued)

Technological Alternatives	Agency Personnel	District Managers	Farmers--Water Users
V.A. Implement an irrigation scheduling system.	No responses.	Irrigation scheduling was tried, but consultants found farmers already doing what they would recommend.	A good job of scheduling is already to be found on most farms.
V.B. Make some changes in irrigation methods and practices.	No responses.	The trickle systems tried have not functioned well. There is limited use of sprinklers on certain soils.	Trickle systems could be adapted to irrigation of trees and vines. Some lands need leveling. Timing or scheduling is a problem on some farms.

Institutional Alternatives	Agency Personnel	District Managers	Farmers--Water Users
I. Implement a discharge permit system.	Return flows are not point sources; the NPDES is not applicable to agriculture; water quality is not a significant problem.	Not applicable to irrigated agriculture in the Valley. If implemented, it could destroy irrigated agriculture.	Not appropriate to irrigated agriculture. Unrealistic standards and discharge permits would eliminate irrigated agriculture.
I.A. Issue permits to the highest local water management authority.	NPDES is not implementable. Reliance will be placed on 208 program. Influent control program considered to be more appropriate to return flows than any other program.	If a permit system is implemented, administration should be located at district level, and controls should be imposed on districts, not farmers.	If this system must be employed, permits should be issued to the districts. Districts could enforce regulations affecting water use on farms better than federal and state agencies.
I.B. Issue permits to individuals who are users of water.	No responses.	To attempt enforcement at water user (farmer) level would be folly.	Wouldn't work.
II. Initiate charges for effluent to reflect quantity and quality of return flows and costs of treatment.	No responses.	Monitoring of return flows, sufficient to implement an effluent tax, would be prohibitively expensive unless the tax were levied on districts.	Might be a good program because it would penalize poor management. It would provide incentive for good management of water.

(continued)

TABLE 15 (continued)

Institutional Alternatives	Agency Personnel	District Managers	Farmers--Water Users
III. Develop incentives for management/control of irrigation return flows.	EIA, New Mexico and Texas Water Quality Board regard irrigation return flows as nonpoint sources to be dealt with in 208 Water Quality Planning efforts. Improved land/water management is key to pollution control.	Incentives for adoption of best management practices will speed up the implementation of these practices.	Incentives are useful to adoption of new and improved methods of water management.
III.A. Provide cost-sharing programs for capital improvements.	No responses.	This would be helpful to district rehabilitation of facilities. The only present subsidy is long-term, low-interest loans. Cost-sharing for improved irrigation equipment on farms would stimulate investment in it.	Major changes in facilities and equipment are facilitated by cost-sharing programs. Cost-sharing reduces the capital requirements for districts and farmers.
III.B. Make incentive payments for improved water management practices.	No responses.	A cost-sharing program like the ACP would stimulate the adoption of best management practices.	Cost-sharing through ACP is already available for certain improved water management practices.
IV. Provide technical assistance in land/water management programs.	No responses.	Will be important to adoption of best management practices.	The SCS could be productively employed in extension of information and assistance in improved water management.
V. Facilitate sales of the annual allotments or fractions thereof at negotiated prices.	No responses.	Transfers of allotments now possible in all three districts.	Transfers of water allotments have been very useful in some years and some circumstances. Instances of transfers are increasing.
VI. Sever the water right from the land and allow transfers (sales) of rights.	New Mexico legislature: "The Water Quality Act does not grant to the commission or to any other entity the power to take away or to modify property rights in water...."	This alternative is being seriously considered in El Paso District where urbanization is creating problems of distribution of water. Perhaps rights should be withdrawn from urbanized lands. Otherwise, it is not a practical alternative.	This alternative is generally not acceptable. Water is needed in agriculture. Sales of rights would cause movement of water into urban and commercial uses.

(continued)

TABLE 15 (continued)

Institutional Alternatives	Agency Personnel	District Managers	Farmers--Water Users
VI.A Limit sales to agricultural users.	No responses.	Most farmers are very concerned about removal of water from agriculture.	This would be necessary to gain approval of such sales.
VII. Add element of water quality to water right.	New Mexico has a specific policy which recognizes a reasonable degradation of water through the exercise of a water right and the subsequent use of the water.	Would require greatly increased monitoring of water use and return flows.	No responses.
VIII. Issue regulations for beneficial use.	The legal authority of the state engineers office (New Mexico) is to insure that water users are beneficially using their water. The statutes say that waste of water is a misdemeanor.	A beneficial use regulation could be enforced at the district level and perhaps should be implemented.	No responses.

constrained by their responsibilities for management of diversion and distribution facilities. They also reflected farmer-member interests, perhaps being more jealous of rights, customs, practices and methods than farmers themselves. Managers were quite conscious of water quality problems and willing to do something about them, even to the point of assuming responsibility for some quality control programs. The sample of farmers interviewed was undoubtedly biased in favor of "better" farmers. They were well-educated, informed, articulate operators of relatively large commercial units, and community leaders. A larger sample would have included some farmers not so well-informed and not so capable of good judgment. But they would have been a part of the affected water users, and should have been included.

Evolution of Solution Packages

The preferred solutions quite obviously include those that are directed to improvement in the management of water in irrigated agriculture. They are technological--the lining of canals and ditches, the measurement of deliveries, the improvement of water application methods--and the institutional--cost-sharing for capital improvements, incentive payments for improved practices, and technical assistance for improved water management. Sales or exchanges of allotments have already been established as useful solutions to problems of efficient use of water. Enforcement of beneficial use provisions got some positive response.

Not favored were controls--permit systems, quality requirements and effluent charges--plus some "far out" technological solutions like weather modification and evaporation suppression.

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APPENDIX A

TABLE A1. SOCIAL CHARACTERISTICS: GENERAL POPULATION

County	General Social Characteristics						
	Median Years of School		Unemployed (%)		Occupation: Farmers and Farm Managers (%)	Median Income	Per Capita Income
	M	F	M	F			
Sierra	9.2	10.5	3.1	4.6	3.6	$4833	$2068
Dona Ana	12.3	12.1	5.4	8.1	2.2	$7395	$2250
El Paso	12.2	11.5	4.9	5.8	0.3	$7792	$2359
Hudspeth	9.5	10.2	1.9	7.3	14.9	$5314	$1652

SOURCE: U.S. Census of Population-1970.

TABLE A2. SOCIAL CHARACTERISTICS: RURAL NONFARM POPULATION

County	Median Years of School	Industry of Employment: Agriculture, Forestry & Fisheries (%)	Occupation: Farmers & Farm Managers (%)		Median Income	Per Capita Income
			M	F		
Sierra	10.0	25.8	2.5	--	$4757	$1894
Dona Ana	8.9	12.4	2.7	--	$5860	$1776
El Paso	8.3	12.3	2.1	--	$6047	$1606
Hudspeth	9.9	21.4	12.7	--	$5175	$1610

SOURCE: U.S. Census of Population-1970.

TABLE A3. SOCIAL CHARACTERISTICS: RURAL FARM POPULATION

County	Median Years of School	Industry of Employment: Agriculture, Forestry & Fisheries (%)	Occupation: Farmers & Farm Managers (%)		Median Income	Per Capita Income
			M	F		
Sierra	10.0	52.9	45.2	--	$5400	$2030
Dona Ana	8.9	57.0	30.1	2.6	$5739	$1684
El Paso	10.1	45.1	20.2	3.6	$6281	$2109
Hudspeth	9.9	66.8	38.0	11.1	$5818	$1776

SOURCE: U.S. Census of Population-1970.

TABLE A4. POPULATION CHARACTERISTICS: 1960 AND 1970

County	Total	1970							1960		
		URBAN				RURAL					
		Total	% Urban	Urbanized Areas	Other Urban	Total	Places 1000-2500	Other Rural	Total	Urban	Rural
Sierra	7,189	4,656	64.8	--	4,656	2,533	--	2,533	6,409	4,269	2,140
Dona Ana	69,773	46,189	66.1	--	46,189	23,584	4,843	10,741	54,948	33,754	26,194
El Paso	359,291	344,938	96.0	337,471	7,467	14,353	3,742	10,611	414,070	280,262	33,808
Hudspeth	2,392	--	--	--	--	2,392	--	2,392	3,343	--	3,343
TOTAL	438,645	395,783				42,862			383,770		

SOURCE: U.S. Census of Population-1970.

TABLE A5. URBAN AREAS IN THE MIDDLE RIO GRANDE VALLEY.

Urban Area	1970	1960	% Change
Truth or Consequences	4,656	4,269	9.1
Las Cruces (area)	43,735	33,754	
Las Cruces (city)	37,857	29,367	28.9
La Mesilla	1,713	N/A	--
University Park-Tortugo	4,165	4,367	28.9
El Paso (City)	332,261	276,687	16.5
El Paso (SMSA)	337,471	--	--

SOURCE: U.S. Census of Population-1970.

TABLE A6. PERCENTAGE CHANGE OF THE POPULATION IN THE MIDDLE RIO GRANDE VALLEY FROM 1960 to 1970

County	Total Population	Urban Population	Rural Population
Sierra	12.2	9.1	18.4
Dona Ana	16.4	36.8	-10.0
El Paso	14.4	23.1	-57.6
Hudspeth	-28.4	--	-28.4
State			
New Mexico	6.8	13.1	-5.3
Texas	16.9	24.1	-4.9

SOURCE: U.S. Census of Population-1970.

TABLE A7. PERCENT OF THE RURAL POPULATION TO THE TOTAL POPULATION IN THE MIDDLE RIO GRANDE VALLEY: 1970

County	% Rural Non-Farm 1970	% Rural Farm 1970
Sierra	23.1	18.9
Dona Ana	26.9	6.6
El Paso	3.3	0.4
Hudspeth	73.1	26.9

SOURCE: U.S. Census of Population-1970.

TABLE A8. TYPE OF FARM ORGANIZATION IN THE MIDDLE RIO GRANDE VALLEY

	Type of Farm Organization						
	Independent Family (%)		Partnership (%)		Corporate (shareholders)		Total %
					10	10	
FARMS							
Sierra	75	(78.1)	13	(13.5)	8	--	(8.4)
Dona Ana	423	(84.6)	54	(10.8)	21	2	(4.6)
El Paso	226	(81.6)	33	(11.9)	17	1	(6.5)
Hudspeth	90	(76.9)	23	(19.6)	4	--	(3.5)
ACREAGE							
Sierra	402,467	(33.0)	107,644	(8.8)	709,302	--	(58.2)
Dona Ana	386,573	(70.4)	90,993	(16.6)	71,021	260	(12.9)
El Paso	232,132	(63.5)	108,438	(29.7)	24,808		(6.8)
Hudspeth	872,566	(55.7)	693,666	(44.3)	N/A	N/A	(--)

SOURCE: Census of Agriculture-1969.

TABLE A9. TENURE OF FARM OPERATORS IN THE MIDDLE RIO GRANDE VALLEY

County	Type of Farm Tenure					
	Full Owners (%)		Part Owners (%)		Tenants (%)	
FARMS THAT HAVE HARVESTED CROPLAND						
Sierra	47	(54.0)	33	(37.9)	7	(8.0)
Dona Ana	345	(51.6)	235	(35.2)	88	(13.2)
El Paso	184	(52.0)	115	(32.5)	55	(15.5)
Hudspeth	39	(47.6)	29	(35.4)	14	(17.1)
HARVESTED ACREAGE						
Sierra	1,527	(31.9)	2,861	(59.9)	392	(8.2)
Dona Ana	18,575	(24.5)	47,758	(62.9)	9,594	(12.6)
El Paso	14,538	(26.3)	30,321	(54.9)	10,405	(18.8)
Hudspeth	8,948	(33.1)	12,990	(48.1)	5,073	(18.8)

SOURCE: Census of Agriculture-1969.

TABLE A10. PERCENTAGE OF IRRIGATED FARM LAND TO TOTAL FARM LAND IN THE MIDDLE RIO GRANDE VALLEY

County	1969 Total	1969 % Irrigated		1964 Total	1964 % Irrigated	
			FARMS			
Sierra	156	84	(53.8)	195	131	(67.2)
Dona Ana	768	633	(82.4)	869	820	(94.4)
El Paso	452	327	(72.3)	403	342	(84.9)
Hudspeth	131	83	(68.4)	139	94	(67.6)
			ACREAGE			
Sierra	1,245,839	5,183	(0.41)	1,147,050	5,626	(0.49)
Dona Ana	644,997	80,700	(12.5)	661,745	91,680	(13.9)
El Paso	386,596	57,966	(15.0)	513,755	60,194	(11.7)
Hudspeth	1,737,284	46,610	(2.5)	1,893,750	37,289	(1.9)

SOURCE: Census of Agriculture-1969.

TABLE A11. ACREAGE UNDER IRRIGATION IN THE MIDDLE RIO GRANDE VALLEY

County	Farm Unit Size in Acres 1-9	10-49	50-69	70-99	100-139	140-179	180-219	220-259	260-499	500-999	1000-1999	2000 +
NUMBER OF FARMS WITH IRRIGATED LAND												
Sierra	3	17	6	8	9	10	3	3	6	6	5	8
Dona Ana	81	178	49	53	53	41	26	28	64	39	12	9
El Paso	77	81	14	14	17	19	11	13	36	31	7	7
Hudspeth	--	4	--	5	1	10	4	1	16	22	6	14
ACRES OF IRRIGATED LAND												
Sierra	7	220	212	391	363	687	365	310	691	333	858	810
Dona Ana	347	3,606	2,319	3,630	5,084	4,626	4,359	4,627	18,968	20,502	6,384	6,348
El Paso	327	1,630	765	874	1,775	2,631	2,044	2,625	11,810	17,162	7,264	9,059
Hudspeth	--	48	--	278	109	1,143	637	233	3,731	9,619	4,547	22,265

SOURCE: Census of Agriculture-1969.

TABLE A12. NUMBER OF FARM UNITS PER ECONOMIC CLASS IN THE MIDDLE RIO GRANDE VALLEY

County	Economic Classes														Total
	$1-2499	2500-4999	5000-7499	7500-9999	10,000-14,999	15,000-19,999	20,000-29,999	30,000-39,000	40,000-59,999	60,000-79,999	80,000 +	Class 6	Part-Time	Part Retirement	Abnormal	
Sierra	1	22	11	11	8	10	14	5	6	3	5	17	30	13	--	156
Dona Ana	25	85	74	43	56	26	41	46	40	17	54	43	168	46	4	768
El Paso	27	41	25	20	25	15	28	18	26	19	38	26	115	27	2	452
Hudspeth	4	7	15	4	12	16	20	11	10	10	10	--	7	5	--	131

SOURCE: Census of Agriculture-1969.

APPENDIX B

SPRINKLER AND TRICKLE IRRIGATION
IN THE RIO GRANDE PROJECT

A conversion from surface methods of irrigation to sprinkler irrigation systems by many of the farmers in the Mesilla and El Paso Valleys would be highly beneficial in terms of efficient water use, with the greatest benefits occurring during drought years. Sprinkler irrigation systems--properly designed, installed and operated--have many advantages, both in terms of water quantity and quality. Uniform water application is possible on all types of soils. A properly designed system should result in no tailwater runoff and drastically reduced deep percolation losses, which would also result in more efficient fertilizer use. Drainage problems would be alleviated and existing surface water supplies would be more effectively utilized. Also, ground water supplies could be easily employed for sprinkler irrigation.

Apart from the water quality benefits, there are many other advantages to farmers in converting to sprinklers. The labor savings are particularly noticeable in comparison with surface irrigation methods. With portable solid-set or permanent set systems, labor is negligible and the systems lend themselves to automation for all water application purposes.

During times of comparatively low water allocation--such as the drought years of the 1950's--the waste of water under surface methods frequently means that farmers must resort to pumping the more saline ground water flows. Since sprinkler systems allow small streams of water to be distributed over a larger area, irrigation can be accomplished where there is insufficient water to irrigate efficiently with other methods.

Associated with the reduction of nutrient losses by reducing deep percolation, further fertilizer loss reduction can be achieved by the ability to use sprinkler systems to apply fertilizers at the time required by the plant. Water soluble fertilizers can be applied through the sprinklers with the timing and amount controlled to meet the needs of the plant. The ability to schedule fertilizer applications to plant needs (rather than to cultural operations as with surface irrigation methods) reduces the opportunity for leaching nutrients below the root zone. The amount of water applied can also be controlled to meet the needs of the crop, with light applications for seedlings and young plants. Water soluble herbicides and insecticides can also be applied through the sprinklers. As drainage problems are alleviated, salt accumulation on the soil surface is reduced. This reduces the hazard to seed germination and plant growth from the accumulated salts.

All of these advantages add up to a potential for cost savings and increased returns for the farmer operators. Generally, one of the major obstacles to adoption of sprinkler irrigation, however, is the high capital cost involved. The cost of converting from surface irrigation methods to sprinklers will vary markedly depending on the particular system adopted and the acreage irrigated. Typical capital costs for different systems (based on installations at Yakima Valley and Grand Valley) show per acre (per hectare) costs ranging from approximately \$250 (\$617/ha) for handmove and sideroll sprinkler irrigation systems, \$800-\$1,000 (\$1,800 - \$2,500) for portable and permanent nonautomated solid-set sprinkler systems, with an additional cost of approximately \$500 per acre (\$1,234 per hectare) for automating such systems.

Trickle or drip irrigation is a recently developed irrigation method and would appear to have potential for orchard crops in the study area. This method of irrigation has gained attention during recent years because of the potential for increasing yields, while decreasing water requirements and labor input. The concept behind trickle irrigation is to provide the plant with the optimal soil moisture environment continuously. This is accomplished by conducting water directly to individual plants, through laterals running along each row, instead of providing water to the entire field as with flood or sprinkler irrigation. The multitude of lateral lines are supplied by manifold lines which connect to the main line which in turn connects to the water source. A control head is provided, generally at the water source, to regulate pressure and flow and to filter suspended solids from the water. A fertilizer injection system is often incorporated into the control head.

A wetted profile, the shape of which is largely dependent on soil characteristics, develops in the plant's root zone beneath the "trickler" or "emitter." Ideally, the area between tree rows is dry and receives moisture only from incidental rainfall. Trickle irrigation saves water because only the plant's root zone is supplied with water and little water should be lost to deep percolation or evaporation under proper management. The only irrigation return flow is that due to a leaching fraction which may be necessary to prevent excessive salt buildup in the root zone. There is no surface runoff and very little nonbeneficial consumptive use of water by weeds. Water savings are affected through the ease with which the correct amount of water is accurately applied.

New Mexico State University has been successfully growing crops with trickle irrigation in recent years. This work should be highly beneficial in implementing trickle irrigation in Mesilla Valley, and perhaps El Paso Valley. In the El Paso Valley, crops are grown with trickle irrigation using domestic water at the Texas A&M University field station.

For irrigating widely spaced crops (e.g., nut trees), the cost of a correctly designed trickle irrigation system is relatively low in comparison to that for other solid-set or permanent irrigation systems. In orchards, the cost of a trickle irrigation system may be lower than that for a solid-set or permanent sprinkler system having the same level of automation. In addition, where clogging is not a problem and emitter line maintenance is minimal, operation and maintenance costs of the trickle irrigation system are usually quite low. However, in plantings of row crops or vines, where the average distance between emitter lines must be less than 10 feet, the cost of trickle irrigation is relatively high.

The cost of a trickle irrigation system for orchard crops is usually slightly more than $1,000 per acre ($2,469 per hectare). The cost of automating trickle irrigation systems is only $100-$200 per acre ($247-494 per hectare).